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Impacts Of Climate Change On Food Security And Smallholder Livelihoods In Northern Ghana

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Abstract

Climate change and food insecurity threaten the livelihoods of smallholder communities in the Global South. In the Ghanaian context, climate change and food insecurity are particularly crucial challenges in the northern regions, where most people are engaged in diverse activities in the agricultural sector. Despite tremendous efforts to curtail food insecurity and climate change vulnerability of smallholder households in northern Ghana, food insecurity and climate change remain pervasive in the region, indicating that smallholder adaptive capacities and resilience to the impacts of climate change are not commensurate with the severity of the problems. Emerging literature has indicated that livelihood diversification strategies and collective household decision-making can potentially moderate the effects of climate change. Yet in the Upper West Region (UWR) of Ghana, we know little about these important links. Therefore, this study draws data from a cross-sectional survey (n=1100) in the UWR to examine smallholder livelihoods and food security situation in the contexts of climate change.

First, the study examined the role of livelihood diversification strategies in households' resilience to climate change. Results from the logistic regression revealed that smallholder households that practiced only farm diversification (OR = 3.95; $p \leq 0.05$) and a combination of both farm and non-farm diversification (OR = 5.77; $p \leq 0.01$) had significantly higher odds of reporting stronger resilience to climate change compared to those who did not employ any diversification strategy. Second, the study examined the relationship between intra-household decision-making arrangements and food security. The regression results indicated that households that practiced joint decision-making (OR = 1.71; $p \leq 0.001$) had significantly higher odds of being food secure than households that practiced sole patriarchal decision-making. The findings from this study point to the need for agricultural policies to harness the synergies between farm and non-farm livelihood activities as complementary climate change risk-spreading strategies. Also, this study reinforces that policies seeking to address food insecurity and

other socio-economic challenges in northern Ghana must focus on the interdependence and complementarity of men and women in household food security decision-making.

Keywords: Livelihood diversification; resilience, climate change; decision making, food security, Ghana

Summary for Lay Audience

Goal 2 of the Sustainable Development Goals (SDGs) aims to eliminate all forms of hunger and malnutrition by 2030. Regardless, nearly one-fourth of the global population do not have access to safe and nutritious food. Ironically, food insecurity is prevalent among food producers, particular smallholder farmers in Sub-Saharan Africa (SSA). The prevalence of food insecurity among smallholder farmers is attributed to climate change and other biophysical and socio-economic factors. In Ghana, climate change and food security present crucial challenges to people's livelihoods, especially smallholder farmers in the northern regions. This shows that smallholder farmers in northern Ghana do not have appropriate coping and adaptation strategies to these problems. Livelihood diversification and collective decision making are promising approaches that could improve food security and climate change resilience in smallholder communities. Livelihood diversification and collective decision making can pull resources from diverse livelihood activities to help households spread risks. Therefore, this thesis examined the potential of livelihood diversification strategies and collaborative decision making in improving resilience to climate change and food security.

Overall, the findings showed that livelihood diversification and collective decision making can improve climate change resilience and food security in smallholder context. Farmers that practiced only farm livelihood diversification were three times more likely to be resilient to climate change than farmers who did not practice livelihood diversification. Similarly, households that combined farm and non-farm livelihood strategies were five times more likely to be resilient to climate change impacts than households that did not practice livelihood diversification. Also, households that practiced collective decision making were more likely to be food secure than households that practiced sole decision making. The findings show that combining farm and non-farm livelihoods is a beneficial initiative in smallholder communities and policies must pay attention to how concurrent diversification into farm and non-farm

livelihood activities could be harnessed to improve smallholder farmers adaptive capacities and livelihoods. The study also suggests that policies and initiatives that want to improve food security should recognize that women and men depend on and complement each other to ensure household food security. Therefore, collective household decision making can help pull resources from different livelihood activities to improve food security.

Co-Authorship Statement

This thesis contains two manuscripts, one is published and the other revised and resubmitted to be considered for publication. Both manuscripts are co-authored with my graduate supervisor, Dr. Isaac Luginaah and other members of the Farmer Livelihood and Agricultural Production (FLAP) project. However, as the first author, I conceptualized and developed each manuscript with the guidance of my supervisor and the other members of the FLAP team. The manuscripts include:

Mohammed, K., Batung, E., Kansanga, M., Nyantakyi-Frimpong, H., & Luginaah, I. (2021). Livelihood diversification strategies and resilience to climate change in semi-arid northern Ghana. *Climatic Change*, *164*(3), 1-23. https://doi.org/10.1007/s10584-021-03034-y

Mohammed, K., Batung, E., Kansanga, M., Nyantakyi-Frimpong, H., & Luginaah, I. Intra-household decision making arrangement and food security in semi-arid northern Ghana. *African Geographical Review (Under review)*

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Chapter 1

1.0 Introduction

This thesis examines smallholder farmers' livelihood strategies in the context of climate change and food insecurity in semi-arid Ghana. This introductory chapter provides an overview of climate change and variability and food insecurity as crucial challenges in Sub-Saharan Africa (SSA) and semi-arid Ghana. The chapter proceeds to state the research objectives, the significance of the research and finally, the structure of the entire thesis.

1.1 Study Background

1.1.1 The climate change emergency

Climate change is now an unequivocal global emergency, evidenced by the unprecedented concentrations of greenhouse gases (e.g., carbon dioxide, methane, and nitrous oxide) in the atmosphere, increased temperatures and increased intensity of extreme climate events (Pisoft et al., 2021; Vajedsamiei, 2021; IPCC, 2018). The high level of greenhouse gases is mainly attributed to human activities. Anthropogenic-induced atmospheric warming exceeded pre-industrial warming by 1.5º C in 2017 and increases between 0.1º C and 0.3º C every decade (IPCC, 2018). Multiple environmental factors such as rising temperatures, rise in carbon dioxide and erratic precipitation patterns interact to create numerous adverse impacts of climate change and variability (IPCC, 2018). There are evidence of rising sea levels, ocean acidification and an increase in occurrence and intensity of extreme climate events such as extreme heat, hurricanes, floods, tornadoes, droughts and wildfires (Chevuturi et al., 2018; IPCC, 2018; King & Karoly, 2017). Climate-sensitive biophysical conditions interact with socio-economic and political instabilities to create high vulnerabilities (IPCC, 2014). Therefore, the severity of

climate change impacts is not a function of only the hazard but a combination of vulnerability (susceptibility and adaptive capacity) and the exposure of communities to climate threats (IPCC, 2018).

Climate projections show that temperatures in Africa will increase above 2º C by the last two decades of the 21st century (IPCC, 2014). Under high Representative Concentration Pathway (RCP), warming in Africa may increase between 3º C and 6º C by the end of the 21st century (IPCC 2018). Consequentially, semi-arid regions in Sub-Saharan Africa (SSA) remain one of the most vulnerable regions to the adverse impacts of climate change and variability (Amjath-Babu et al., 2016; Riede et al., 2016a). Agriculture is perhaps the most susceptible sector to climate change impacts in SSA. Since smallholder farmers in SSA are heavily reliant on rain-fed agricultural systems and the region is projected to experience high warming, smallholder farmers are burdened with one of the most severe adverse effects of climate change and variability (Asare-Nuamah & Botchway, 2019; Assan et al., 2018). The burden of climate change among smallholder farmers will likely include extreme events such as storm surges, erratic rainfall, floods and drought (IPCC, 2018). While climate mitigation is necessary for SSA, there is an urgent need to build adaptation and resilience to climate change among smallholder farmers.

Climate change adaptation and resilience in Africa remain low and ineffective due mostly to dysfunctional government policy. Adaptation strategies and initiatives in Africa are not commensurate with the region's level of climate change burden (IPCC, 2014). According to the IPCC (2018), the ability to spearhead climate adaptation knowledge and strategies is dependent on the amount, quality and reliability of available climate data. Therefore, a significant constraint in Africa's inability to adapt to climate change is the lack of quality and reliable climate data (IPCC, 2018). Also, a key challenge for climate adaptation in SSA is policy lags. There is a lack of coordinated policy implementation in most SSA. Adaptation strategies in Africa are primarily autonomous, especially among smallholder farmers

(Dapilah & Nielsen, 2019; Alam et al., 2017; IPCC, 2014). Smallholder farmers are often engaged in autonomous adaptation strategies with less support from the government (Assan et al., 2018; Alemayehu & Bewket, 2017). More so, multiple factors that burden smallholder farmers aside from climate change (Nyantakyi-Frimpong & Bezner-Kerr, 2015), autonomous adaptation among smallholder farmers may be geared towards building resilience to one or multiple stressors (Riede et al., 2016; Carr, 2008). Therefore, it is essential to understand how smallholder farmers could harness local autonomous adaptation strategies to build climate change resilience (Adger et al., 2003).

In the Ghanaian context, smallholder farmers struggle to build adaption and resilience to climate change amid multiple stressors (Assan et al., 2018; Nyantakyi-Frimpong, 2013). The climate burden is particularly severe in the semi-arid regions of Ghana, where more than 70% of households depend primarily on rain-fed subsistence farming (Ghana Statistical Service, 2019; Asravor, 2018). Like most semi-arid regions in SSA, there is a lag between planning and policy implementation on climate change adaptation and resilience in the semi-arid regions of Ghana. Therefore, farmers in the region resort to migration and livelihood diversification as spontaneous responses to these multiple stressors (Kuuire et al., 2013; Luginaah et al., 2009). Livelihood diversification has been acknowledged as a strategy that could be harnessed for local adaptation to stressors among smallholder farmers (Adzawla et al., 2019; Asravor, 2018; Ellis, 2000). The fundamental rationale for livelihood diversification is that multiple livelihood activities would help spread risk. However, there is limited understanding of how different livelihood strategies (farm and non-farm) may improve smallholder livelihoods and resilience to environmental stressors. Thus, this study seeks to understand the role of livelihood diversification strategies in resilience to climate change in the semi-arid regions of Ghana.

1.1.2 The menace of food insecurity

Another global menace closely related to climate change is food insecurity. Food security exists "when all people, at all times, have physical, social and economic access to sufficient, safe and nutritious food" (FAO, 2009: 1). Therefore, food security is not limited to the mere availability of food, but includes the accessibility and utilization of food sustainably (FAO et al., 2018). The Climate change burden on agriculture in SSA interacting with socio-economic factors primarily drives food insecurity in the region (FAO et al., 2020; IPCC, 2014; Riede et al., 2016). Notwithstanding the global attention to food insecurity, an estimated 2 billion people are food insecure globally (FAO, FAD, et al., 2020). As indicated in Figure 1.1, about one-third of food insecure people live in Africa, most of whom are smallholder farmers in SSA (FAO, FAD, et al., 2020). Also, Africa will account for more than half of all undernourished people by 2030 (FAO, FAD, et al., 2020). Thus, hunger and undernourishment are especially pressing concerns in SSA, where climate change, inequalities, and political instability exacerbates food insecurity (FAO et al., 2020).

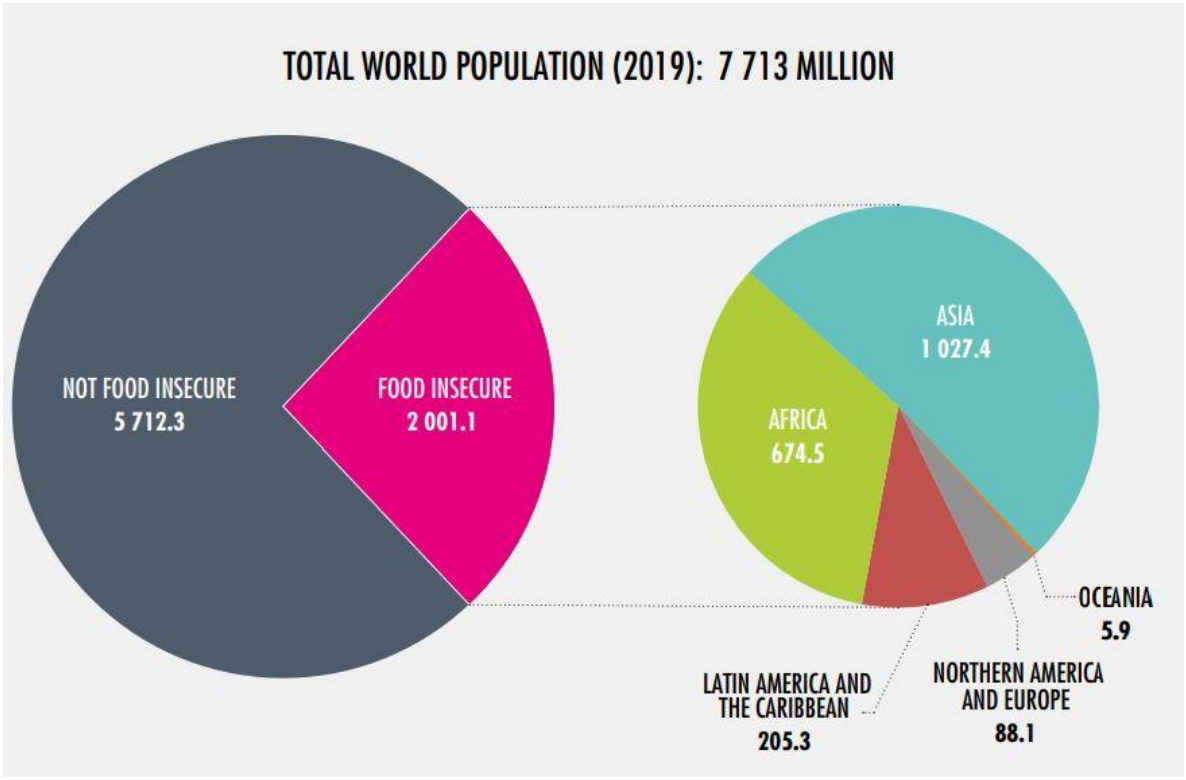

Figure 1. 1: Global food insecurity

Note: The number of food insecure/food secure people are in millions

Source: FAO, FAD, UNICEF, WFP, WHO, 2020

In Ghana, there are local disparities in food insecurity. Food insecurity is high in northern Ghana compared to southern and the middle zone of Ghana. For example, while food insecurity prevalence in southern Ghana is below 7%, the prevalence of food insecurity in northern Ghana is between 10% and 30% (Nyantakyi-Frimpong, 2013; Biederlack & Rivers, 2009). Multiple factors account for the regional disparities in food insecurity prevalence in Ghana. The prevalence and impacts of climate change stressors such as drought and erratic rainfall patterns are high in northern Ghana (Dapilah & Nielsen, 2019; Asravor, 2018). These climate change stressors hinder agricultural production, which is the primary source of livelihood for many communities in northern Ghana (Nyantakyi-Frimpong, 2021; Adzawla et al., 2019). Also, socio-economic factors such as impoverishment, low levels of education,

poor transportation infrastructure, high social inequality and policy marginalization heighten hunger and malnutrition in northern Ghana (Atuoye et al., 2019; Yaro, 2013; Luginaah et al., 2009).

Developmental and scholarly discussions on improving food security is largely skewed towards increasing food production by mitigating the physical constraints of production (e.g., input-intensive agriculture, improved infrastructure, use of drought resistant crops.). For example, the Ghana government under Planting for Food and Jobs initiative seeks to improve food production through increased access to farm inputs (e.g., seeds, machinery, fertilizers, pesticides) and extension services (MOFA, 2019). The social mechanisms that influence access, production, and food utilization are often given a short shrift in ongoing discussions about food insecurity. Therefore, the study shows how intra-household decision-making and gender relations continue to be a vital underlying social driver of hunger and malnourishment in northern Ghana and similar context in SSA.

1.2.3 Study context

Upper West Region is located at the north-western tip of Ghana between longitudes 1º 36' to 3º West and latitudes 9º 48' to 11º North as shown in Figure 3.1. The region covers a total land size of 18,476 km^2, which is 12.7% of the total land area in Ghana. Upper West Region is bounded to the north and west by Burkina Faso, to the south by Savannah Region and the east by Upper East and North East Regions. Upper West Region has a total population of 702,110 (Ghana Statistical Service, 2019). The region has 11 administrative districts with Wa Municipal as the capital. Agriculture is the main economic activity in Upper West, thus majority of people are engaged in smallholder farming practices and other activities in the agricultural chain (Atuoye et al., 2019; Ghana. Statistical Service, 2013; Luginaah et al., 2009). Figure 3.1 shows a map of Upper West Region and the selected districts.

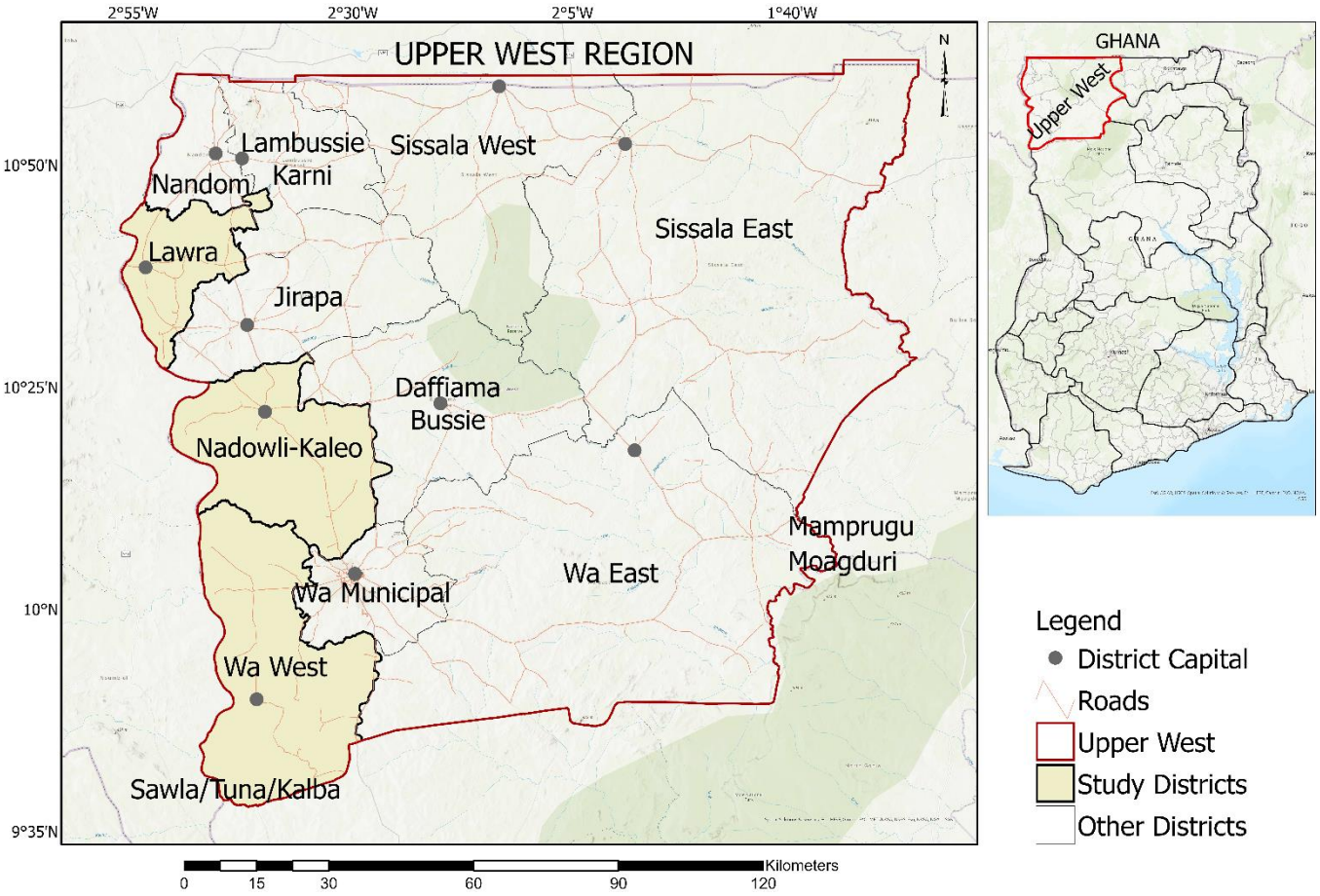

Figure 3. 1 Map of Ghana indicating the Upper West Region

Upper West region has two ecological zones, which are the Guinea and Sudan savannah ecological zones. Areas within the Guinea savannah ecological zone have total annual precipitations of about 1000mm. The Sudan savannah ecological zones have total precipitations between 500mm to 700mm (Ghana. Statistical Service, 2013). Both ecological zones have unimodal precipitations patterns (usually between June to September), which present significant challenges to rain-dependent agricultural systems crop production all year. Also, harsh climatic conditions (e.g., severe droughts, floods, inconsistent precipitation patterns) exacerbate the challenges of agricultural systems in the region. The region has average temperatures of 28°C and peaking at about 38°C. Temperatures in the region has increased by 1.7°C in the last decades and is projected to increase by 3°C by 2050 (Adiku et al., 2017).

Due to the high temperatures, evapotranspiration is equally high, affecting the water retention capacity of soils (Adiku et al., 2017). Consequentially, people in the Upper West Region are increasingly diversifying their livelihoods and migrating to other regions in Ghana in response to the rapid climatic changes (Mohammed et al., 2021; Kuuire et al., 2013; Luginaah et al., 2009). Aside from subsistence agriculture, households engage in alternative livelihoods such as petty trading, small-scale mining, weaving, and brewing local alcoholic drinks (e.g., pito). Therefore, it is imperative to understand how the diversification of livelihoods into farm and non-farm activities may affect households' resilience to climate change in such context.

Food insecurity is another critical challenge in the Upper West Region. Upper West Region has one of Ghana's highest food insecurity rates, with an estimated 18% of the population being food insecure (Essilfie et al., 2020). Food insecurity in the region is primarily due to climate change and variability interacting with socio-economic challenges (Atuoye et al., 2019; Luginaah et al., 2009). For example, the Upper West Region is one of the poorest regions in Ghana. Among every ten people, nine live on less than a dollar daily (Ghana Statistical Service, 2013). The three study districts rank among the poorest districts in Ghana. Wa West ranks number as the poorest district among the 260 districts in Ghana with a poverty incidence of 92.4%. Lawra and Nadoeli-Kaleo ranks 13th and 17th poorest districts (Ghana Statistical Service, 2019). Structural gender inequalities further exacerbate the disproportionate burden of food insecurity. Men are the primary custodians of productive resources under the patriarchal system. For example, under the patrilineal land tenure systems, men are the custodians of lands through inheritance (Kansanga et al., 2019). Therefore, women mainly access lands through other male family members or relatives. The patriarchal system coupled with the practices of polygamy hinders women's role in household decision making concerning the mobilization, production and allocation of household resources. Despite some progress, structural gender inequalities persist in the Upper West Region,

particularly among smallholder farmers in rural areas (Nyantakyi-Frimpong, 2019). Given the contextual climate change and food insecurity burden of the Upper West Region, it is imperative to ezplore pathways of improving climate change resilienc e and food security in the region.

1.2 Research questions

Numerous studies have explored diverse pathways for facilitating climate change adaptation and resilience among smallholder farming communities (see Nyantakyi-Frimpong, 2021; Adzawla et al., 2019; Atuoye et al., 2019; Asravor, 2018; Arouna et al., 2017). For example, studies such as (Adzawla et al., 2019; Asravor, 2018; Ellis, 2000) have explored the opportunities of livelihood diversification as a coping strategy in smallholder context. However, the potential of livelihood diversification in improving climate change resilience remains less understood. Discussions on livelihood diversification have also mainly focused on diversification outside agriculture, with little emphasis on opportunities within agricultural livelihoods. This study explores the relationship between livelihood diversification strategies (i.e., farm and non-farm) and resilience to climate change in smallholder households in northern Ghana.

Similarly, discussions on food security focus strongly on biophysical challenges of food production (e.g., precipitation, temperature, soil, food loss and waste) (Adeyeye, 2017; Alexander et al., 2017; Arouna et al., 2017; Armah et al., 2011). We know little about how social factors (e.g., gender, decision making) shape food security in smallholder farming communities. Few studies that explore social determinants (e.g., gender) of food security have often used qualitative methods. The small size of such studies makes generalization difficult and thus challenging to inform food policy. In response, this study's overarching research question is: how do smallholder households' livelihoods and decision-making influence household food security and climate change resilience? Thus, the key research objectives for this study are:

1. Examine the relationship between livelihood diversification strategies and resilience to climate change in semi-arid Ghana.
2. Investigate the association between intra-household decision-making arrangements and food security in semi-arid Ghana.

1.3 Research significance

This study is essential for literature and policy amid the devasting impacts of climate change and food insecurity in semi-arid Ghana. First, the study will contribute to literature by offering an alternative empirical narrative in understanding the risk-spreading role of farm and non-farm livelihood activities as complementary livelihood diversification strategies. Given the ongoing climate change crisis, discussions around food insecurity focus heavily on biophysical constraints to food production. This study will contribute to the literature on how social mechanisms such as gender relations in decision-making shape household food security outcomes. On the policy front, the study will provide indicators for agricultural and rural development policies to broaden, incorporate and promote livelihood diversification strategies for sustainable livelihoods and climate change adaptation. Also, the study will provide insights for gender transformative policy approaches that are inclusive of all household members in addressing gender inequality in the control of productive resources for household food security.

1.4 Thesis structure

This thesis consists of six (6) chapters. Chapter one is the introductory chapter. It provides a general overview of the challenges of climate change and variability, and food insecurity in Ghana. The chapter also states the research objectives and highlights the significance of the thesis/study. Chapter (2) two is the literature review. It provides a overview of literature on global and local climate change and variability. The chapter also discusses the menace of food insecurity (i.e., at global and regional levels)

and the major facets and conceptualization of food security. The chapter further expatiates the conceptual and theoretical underpinnings of the thesis.

Chapter three is the methodology. The chapter highlights the detailed methods used in the study. First, the chapter presents a brief overview of climate change, food insecurity and other socio-economic factors in the study context. Then it briefly explains the epistemology of this research. The chapter proceeds to discuss the study design, data collection and sampling techniques and the data analytical techniques. Chapter four (4) and five (5) present the two manuscripts in the thesis. Chapter four (4) presents a manuscript that examines the livelihood diversification strategies and resilience to climate change in semi-arid Ghana. This manuscript is published in Climatic Change. Chapter five (5) examines the association between intra-household decision making arrangements and food security in semi-arid Ghana. This manuscript is revised and resubmitted to the journal African Geographical Review for consideration. The two manuscripts are integrated into the thesis as they explore twin challenges (climate change and food insecurity) that plague smallholder farmers in semi-arid regions of Ghana.

Lastly, chapter six (6) summarizes the entire study. The chapter highlights the study's key theoretical and empirical contributions to literature on smallholder livelihoods, climate resilience, and food security in smallholder communities. Also, the chapter presents suggested policy directions for improving climate resilience and food security in semi-arid Ghana and similar context in SSA. Directions for future studies are also presented in this chapter.

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Chapter 2

2.0 Literature Review

2.1 Introduction

This chapter explores the literature on vulnerability to climate change, food insecurity, smallholder livelihoods that have served as the underpinning for responding to the thesis objectives. The chapter also discusses climate change resilience of smallholder farmers, emphasizing ecological and social systems resilience. The livelihood diversification strategies in smallholder communities is also discussed. Lastly, the chapter presents the broader theoretical framework that informs this research.

2.2 Overview of climate change and variability

Human activities and impacts on the environment have thrust the earth into a new geologic epoch known as the Anthropocene. Though contested, the Anthropocene refers to a geologic age where anthropogenic activities are chiefly responsible for environmental transformation such as climate change and variability (Lewis & Maslin, 2015). According to the IPCC (2018), anthropogenic-induced global warming reached an estimated 1º C above pre-industrial levels in 2017 with an average increase of 0.2º C every decade (see Figure 2.1). The IPCC report on 'Global warming of 1.5º C' stipulates that an increase in regional temperatures by 1.5º C or more will increase the occurrence and severity of extreme climate events (IPCC, 2018). The adverse effects of climate change and extreme events may include ocean acidification, rising sea levels, droughts, floods, heatwaves, droughts and storm surges (Dapilah & Nielsen, 2019; Kom et al., 2019; IPCC, 2018; Funk et al., 2012; Boko, 2007). Therefore, one of the key objectives of the Paris Agreement is to deter an increase in global temperatures above 2º C with a more optimistic aim of limiting temperature increase to below 1. 5º C (IPCC, 2018). Consequentially, there is regional variation in warming, with some regions already experiencing warming above 1.5º C and 2º C (IPCC, 2018).

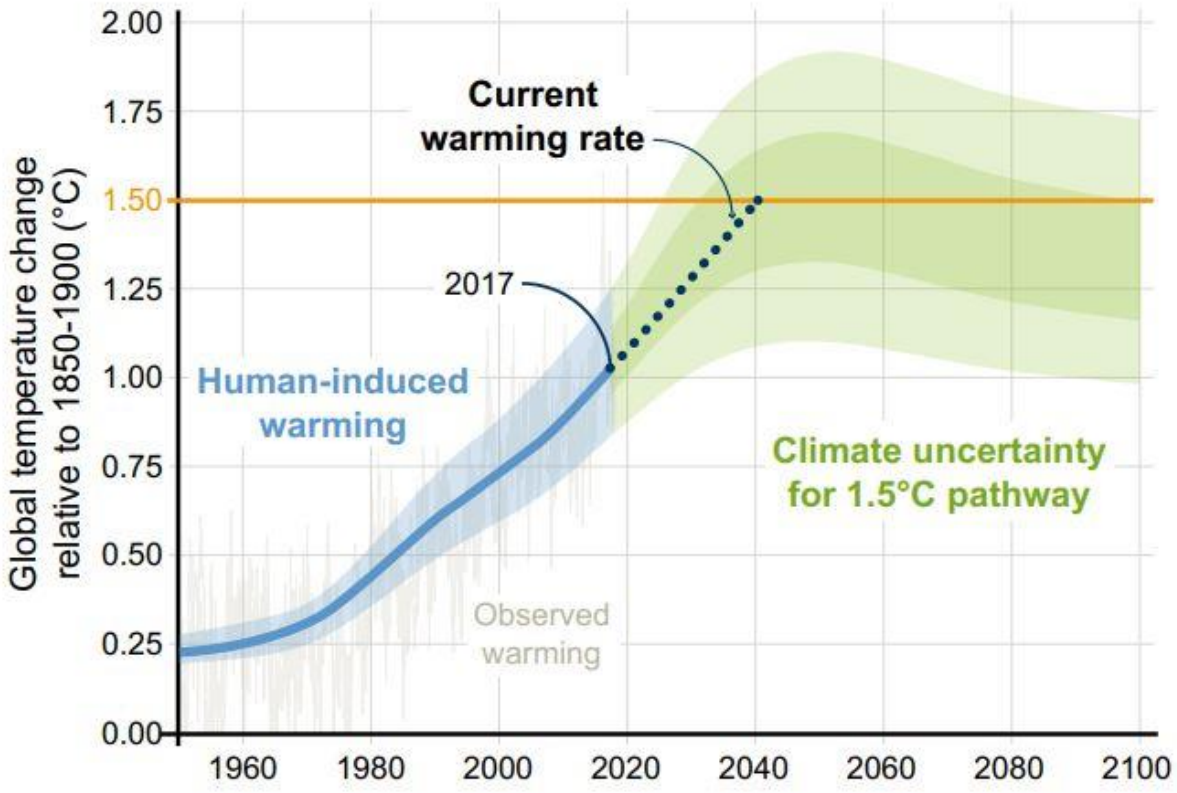

Figure 2. 1: Anthropogenic induced global warming

Note: Human-induced warming reached an estimated 1º C in 2017. Global temperatures are expected to reach 1.5º C by 2040.

Source: IPCC, 2018

In Africa, climate models predict an increase in temperatures that exceed the global average, especially in the arid Sahel regions (Nikulin et al., 2018; Riede et al., 2016). An additional 0.5º C further warming (from the global average of 1.5º C—2º C) is expected in Africa, significantly increasing associated extreme events (Nikulin et al., 2018). The climate in African sub-regions has evolved in recent decades, as evidenced by the increasing temperatures, and shifting precipitation patterns. In West Africa, climate models project an increase of 3º C — 6º C towards the end of the 21st century, subject to different emission scenarios (Riede et al., 2016). The West African countries such as

Guinea, Senegal, la Cote d'Ivoire and Ghana experienced significant warming ranging from 0.2º C to more than 0.5º C (Sylla et al., 2016). West Africa is expected to experience a rapid increase in minimum temperatures compared to maximum temperatures (Nicholson, 2013; Funk et al., 2012). Although there may not be an extreme increase in maximum temperatures, land surface temperatures in the West African Sub-regions will likely increase faster than global averages. (Funk et al., 2012; Riede et al., 2016).

In Ghana, climate models predict similar temperature patterns that are generally consistent with global assessments. Ghana has experienced an average increase in temperature of 1º C per decade since 1960 (Pinto et al., 2012). During the same period, there has been a 2.4% decrease in precipitation. The mean annual temperature in Ghana is projected to increase between 1º C - 3º C by 2060 and 1.5º C to 5.2º C by 2090 (Pinto et al., 2012). Despite slight variations, climate change models have consistently projected that temperatures will increase more in northern Ghana than in the rest of the country (Klutse et al., 2020; Mcsweeney et al., 2010). For example, Table 2.1 shows that total precipitation has decreased by an average of 27.58mm over 20 years (Ministry of Food and Agriculture et al., 2020). Similarly, there has been a decline in total precipitation of 54.80 from 2019 to 2020 (Ministry of Food and Agriculture et al., 2020).

Table 2. 1 Changes in amount and pattern of precipitation (mm) in Ghana

Month	2019	2020	20 Year Average	% Change (2019/2020)	% Change (2020/20 Year Average)
July	205.75	131.76	143.75	-21.92	-9.099
August	113.90	76.1	134.90	-19.89	-26.74
Septemeber	194.60	124.35	180.09	-22.02	-21.50
Total rainfall	514.25	332.21	458.74	-21.50	-24.69

Average rainfall	171.42	110.74	152.91	-7.168	-8.23

Source: Ministry of Food and Agriculture et al. 2020

2.2.1 Vulnerability of smallholder agriculture to climate change

The IPCC defines climate change vulnerability as the extent to which a social or natural system is susceptible or unable to cope with climate hazards (IPCC, 2014). By this definition, vulnerability is a function of adaptive capacity, sensitivity, and exposure of a system to climate hazards. Although Sub-Saharan Africa (SSA) remains a minor emitter of greenhouse gases (IPCC, 2018), the region will likely experience one of the most severe adverse impacts of climate change (IPCC, 2018; Nikulin et al., 2018; Sylla et al., 2016). Several economies and livelihoods of countries in SSA remain vulnerable to climate change (Kom et al., 2019; Amjath-Babu et al., 2016; Antwi-Agyei et al., 2014). Agriculture in SSA is climate-sensitive and vulnerable due to rain dependency and the low adaptive capacity of the agricultural sector (Boko et al., 2007). In recent years increasing temperatures and fluctuating precipitation patterns present significant challenges for timely cultivation in smallholder communities (Riede et al., 2016; Nicholson, 2013). The region has experienced an increase in the occurrence and severity of extreme climate events such as droughts, floods, and storm surges which tend to impact crop production and animal rearing in semi-arid regions (Dapilah & Nielsen, 2019; IPCC, 2018). Furthermore, climate change is expected to lead to an increase in the outbreak of pest and disease that affects crops and animal production (IPCC, 2014; FAO, 2009). A key example is the outbreak of locusts in East Africa. Increase in pests and diseases may lead to increase in post-harvest loss, which is a direct reduction in food supply (FAO, 2009). The increased occurrence of climate change-induced disasters, health concerns and migration can significantly degrade agricultural labor, assets and infrastructure (Pinto et al., 2012).

The relationship between agriculture and climate change is complex. While agriculture remains one of the most vulnerable sectors to the adverse impacts of climate change and variability, the agricultural sector is the second-largest emitter of greenhouse gases globally (Qiao et al., 2019; FAO, 2015). According to FAO (2015), agriculture accounts for nearly 22% of global Greenhouse gases (GHG). GHG emissions from agriculture are largely from the use of machinery in cultivation, burning of biomass, and fertilizers. However, agriculture can be crucial in offsetting greenhouse gas emissions by serving as carbon stocks for sequestration of carbon dioxide into biomass and soil organic matter (Qiao et al., 2019; Johnson et al., 2007). Therefore, the net impact of agriculture on climate change is a function of the two opposing impacts on GHG (i.e., carbon emission versus carbon sequestration). The complex relationship between agriculture and climate change is particularly a challenge for countries in the Global South that still have agriculture as the backbone of their economies (Qiao et al., 2019; Pinto et al., 2012). Developing economies in SSA are juggling increasing agricultural production, reducing GHG emissions from agriculture and increasing carbon sequestration through agriculture. Therefore, it is pertinent to sync adaptation strategies to mitigation in SSA.

Like other countries in SSA, Ghana still has agriculture as a major driver of its economy, dominated by smallholder farmers who cultivate about two hectares of land (Ministry of Environment, Science, Technology and Innovation, 2013). Smallholder farming in Ghana is particularly dominant in semi-arid northern Ghana, where about 80% of households are engaged in diverse livelihoods in the agricultural sector (Ghana Statistical Service, 2019). Several factors make smallholder farmers in semi-arid northern Ghana more vulnerable to adverse climate impacts in the face of climate change. First, agriculture in semi-arid northern Ghana is almost entirely rain-fed with a single cultivation period per year and very high average temperatures (Dapilah & Nielsen, 2019). This limits multiple cultivations within a year, making the region exposed to climate hazards (Bellon et al., 2019; Dapilah & Nielsen,

2019). Also, northern Ghana shoulders about 80% of all impoverished people in Ghana despite constituting only 22% of the entire Ghanaian population (Ghana Statistical Service, 2019). The high levels of poverty in the region thwart the adaptive capacity of smallholder farmers (Dapilah & Nielsen, 2019). More so, the climate sensitivity of smallholder farmers as evidenced by the underlying poor socio-economic conditions, marginalization and conflicts that characterize the region (Ministry of Environment, Science, Technology and Innovation, 2013; Yaro, 2013). Thus, there is a need for effective and efficient climate adaptation and coping strategies in the region. Building and increasing smallholder climate resilience can increase their adaptive capacity and decrease their overall climate vulnerabilities (IPCC, 2014).

2.2.2 Climate change adaptation and resilience

Climate change and variability unquestionably present numerous adverse impacts on the environment and livelihoods of people. Therefore, societies need to employ adaptation and mitigation measures commensurate with the climate change threat (Leisner, 2020). While climate mitigation is a vital long term solution to climate change, there is also an urgent need to improve climate change adaptation and resilience to deal with the current adverse impacts (Bellon et al., 2019; Asravor, 2018; Loison, 2015; Haggblade et al., 2010; Barrett et al., 2001).

Climate change adaptation involves adjusting to current or anticipated climate related consequences (IPCC, 2014). Overall, climate change adaptation in Africa is low (IPCC, 2014). Disaster risk reduction, infrastructural adaptations, social protections and livelihood diversification are reducing vulnerability, however, these are mainly in secluded initiatives (Dapilah & Nielsen, 2019; Asravor, 2018; Loison, 2015). Adaptation in SSA remains autonomous and reactive with few efforts to harness adaptative strategies. According to the IPCC (2014), there are five principles for building effective

climate change adaptation: (i). supporting autonomous adaptation strategies through policies that acknowledge the multiple stressors of livelihoods; (ii). An emphasis on equality and equity in cultural adaptation strategies by increasing the participation of vulnerable groups (e.g., youth, poor, women) in adaptation policy; (iii) incorporating adaptive management, institutional and social learning processing into all levels of adaptation strategies; (iv) integrating flexible and iterative approaches with technology, indigenous knowledge and scientific methods to develop adaptation strategies; (v) and lastly building climate change resilience amid future climate, economic and social uncertainties. In the climate change discourse, adaptation is inextricably linked to resilience. Climate adaptation strategies are critical for improving the overall climate change resilience of households in smallholder contexts.

Climate resilience denotes the ability of households to anticipate, prepare and absorb climate stress without losing their function and structure (Adzawla, Kudadze, et al., 2019; Holling, 1973). Therefore, building and increasing climate resilience is essential for smallholder farmers to adapt to the adverse impacts of climate change (Adzawla, Kudadze, et al., 2019; Assan et al., 2018). In Ghana, stakeholders in the climate discourse have recognized the low climate resilience of smallholder farmer households and the need for effective adaptation (Appiah et al., 2018; Assan et al., 2018; Ministry of Environment, Science, Technology and Innovation, 2013). Hence, numerous strategic measures have been initiated to improve the resilience of smallholder farmers (Assan et al., 2018). For example, the Ghana National Climate Change Policy Report outlined policy strategies to improve farmers' resilience to climate change. These included: improving research on climate-smart agriculture, promoting innovative technologies in irrigations and instituting risk transfer systems such as farm insurance (Adzawla, Kudadze, et al., 2019). Also, Ghana's government and NGOs have made efforts to improve the resilience of the agricultural sector through recycling of agricultural waste, improving access to markets and improving storage and processing facilities (Ministry of Environment, Science, Technology

and Innovation, 2013). Nevertheless, such initiatives have only done very little in improving smallholders' adaptive capacity and resilience to climate change, thereby leaving local people to rely on their livelihood diversification strategies for survival.

2.3 Livelihood diversification strategies

Livelihood diversification is widely recommended as a pathway for reducing vulnerability to climate change in smallholder communities (Adzawla, Baumueller, et al., 2019; Bellon et al., 2019; Asravor, 2018; Müller et al., 2014). Livelihood diversification is the practice by which households build a diverse range of activities and social support abilities to improve and sustain their living standards (Ellis, 1998). The various types of smallholder livelihood diversifications are broadly categorized by sector (farm and non-farm), function (self-employment and wage employments) and location (on-farm and off-farm) (Barrett et al., 2001; Ellis, 1998; Saith, 1992). Most academic literature on livelihood diversification has conceptualized diversification by sector because it effectively distinguishes between agricultural and non-agricultural livelihood activities (Loison, 2015). Therefore, I have conceptualized smallholder livelihood diversification by sector (farm and non-farm) in this thesis.

Farm/agricultural diversification strategies involve smallholder farmers engaging in a variety of primary production of raw agricultural produce to diversify risk and reduce vulnerability to climate change stressors (Ellis, 1998). These livelihood activities include primary crop production diversity and livestock production diversity (Asravor, 2018; Antwi-Agyei et al., 2014). Farm livelihood diversification is not necessarily cultivating a different variety of crops or livestock but includes incorporating diverse farm management practices (Asravor, 2018). Crop and livestock diversification is not alien to smallholder farmers in northern Ghana (Asravor, 2018). Nevertheless, planting high-value crops and agricultural produce aside from the regular subsistence crops are now commonly practiced in semi-arid Ghana (Ministry of Food and Agriculture, 2019). These practices help smallholder farmers adapt to

adverse climate impacts by diversifying risk among different agricultural products (Antwi-Agyei et al., 2014; Ensor et al., 2014).

Non-farm/non-agricultural livelihood diversification is where smallholder farmers engage in alternate activities entirely outside their farms or primary agricultural production for livelihood security (Loison, 2015; Barrett et al., 2001; Ellis, 1998). Ellis (1998) classifies non-farm livelihood diversification into subcategories comprising; i) non-farm rural self-employment, ii) property income, iii) non-farm rural wage employment, iv) urban-to-rural remittance, v) and international remittance (Ellis, 1998). Dapilah and Nielsen (2019), indicated that social support is another key non-farm livelihood that needs to be taken into account when investigating livelihood diversification among smallholders. In the context of smallholder farmers in semi-arid Ghana, non-farm livelihood diversification is widely employed during the dry season when agricultural activities are put on hold because of the rain-fed agricultural systems (Assan et al., 2018). However, in recent times, non-farm livelihood diversification is practiced all year round in smallholder communities.

Dapilah et al. (2019) suggested that smallholder livelihood diversification is context-specific and as such, might conflict with other forms of livelihoods and likely thwart future climate adaptations and resilience. For example, Dapilah et al. (2019) discovered that vegetable production along riverbanks was a wide diversification strategy practiced by smallholders. However, this had adverse effects on fishery and river water availability and quality. Thus, the link between livelihood diversification strategies and poverty reduction and climate resilience is complex and requires more nuanced understanding (Haggblade et al., 2010).

2.4 Overview of food insecurity in Africa

The eradication of hunger and malnourishment remains an integral part of the Sustainable Development Goal (SDG), yet about 2 billion people are food insecure and 689 million people undernourished (FAO

et al., 2020). The burden of food insecurity greatly varies geographically. For example, Asia and Africa jointly account for about 85% of all food-insecure people globally. Nearly 1 billion people in Asia and 675 million people living in Africa are food insecure (FAO et al., 2020). However, it is essential to note that Africa is only 17% of the world population compared to Asia, which accounts for 60% of the world population (Leridon, 2020). To put this into perspective, over half of Africa's population is food insecure (FAO et al., 2020). In contrast, about 22% of people living in Asia are food insecure as indicated in Figure 2.2. Similarly, Figure 2.3 indicates that though Africa currently accounts for 36% of global malnourishment, Africa is projected to surpass Asia and account for more than half of global malnourishment. Given the current trend of events, Africa is not on track to attain zero hunger by 2030.

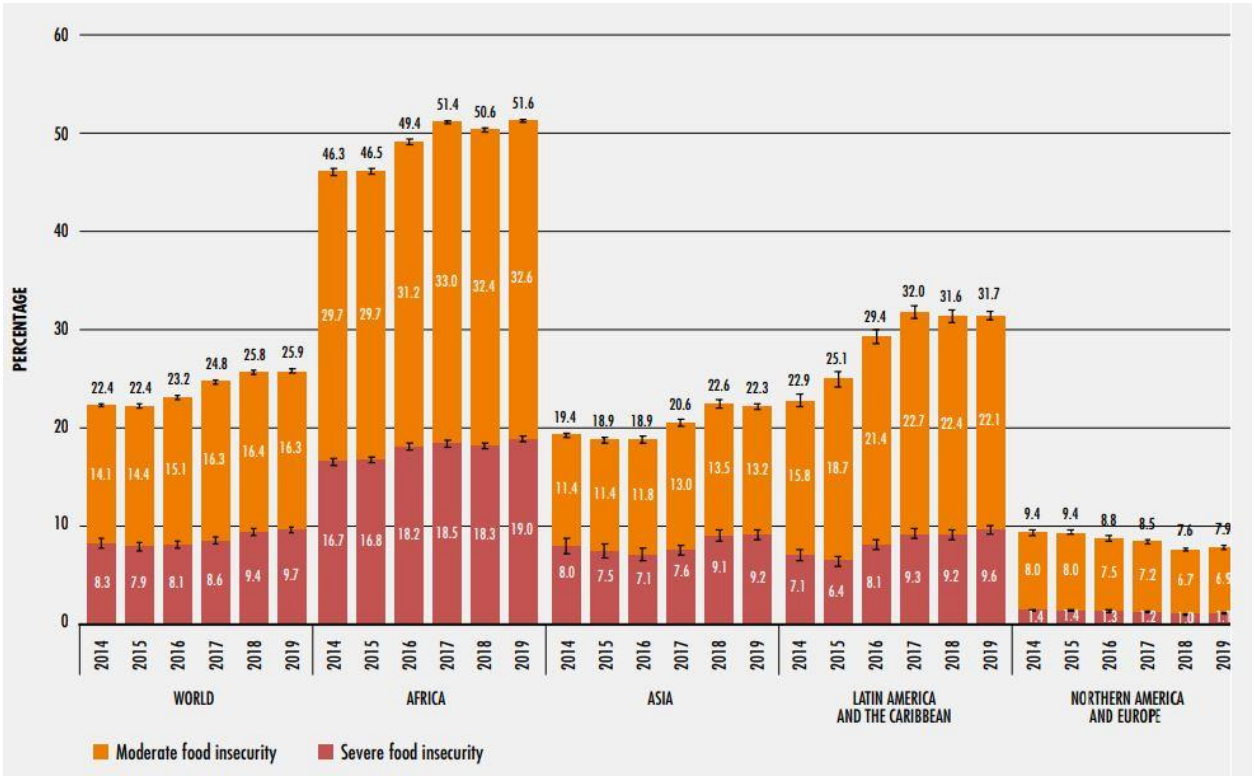

Figure 2. 2: Proportion of food insecure populations by continent.

Source: FAO et al., 2020

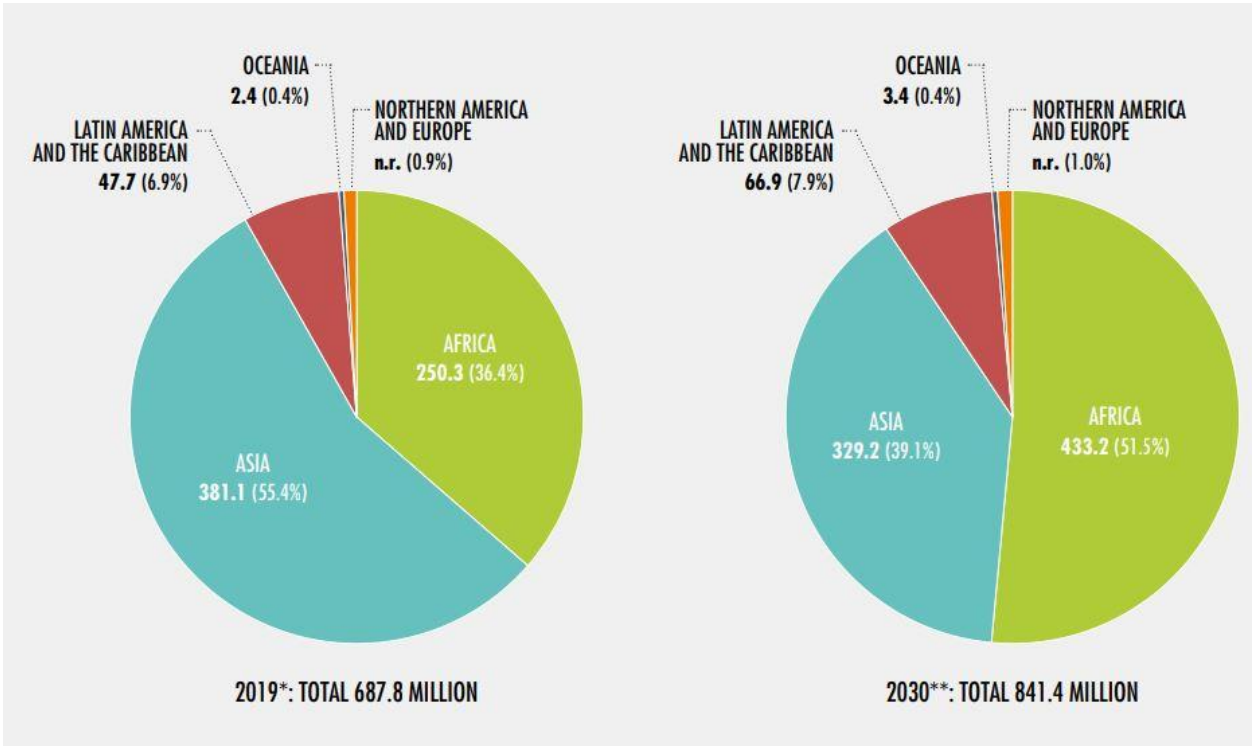

Figure 2. 3: Current and predicted rates of malnourishment by continent.

Source: FAO et al. 2020

Multiple factors are credited for the increasing trend of hunger and malnutrition and the disproportionate burden on Africa. A cumulation of environmental, socio-economic and cultural factors mainly makes Africa vulnerable to food insecurity (FAO et al., 2020; IPCC, 2018; Nikulin et al., 2018). Climate change remains a crucial cause of food insecurity in Africa due to Africa's heavy reliance on rain-fed agricultural production. High intra-and inter-seasonal climate variability coupled with severe floods and droughts negatively affects crop and animal production in Africa (IPCC, 2014). The inability of Africa to adapt to these climate change and variability stressors heightens climate change consequences such as diminished yields, pests and diseases, and post-harvest losses (IPCC, 2018). For example, crop yields have decreased significantly in Africa, from a minimum of 2% for crops such as

sorghum to about 35% for wheat by 2050 (Leisner, 2020; IPCC, 2014). Also, post-harvest losses account for nearly 20% to 30% of Africa's food loss, which is valued at about 1.6 billion USD (FAO, 2009). Further, high poverty rates in Africa mean that households do not have adequate purchasing power to access safe and nutritious food (FAO et al., 2020). The high number of conflicts in most African countries also exacerbates food insecurity by limiting food availability, accessibility and utilization (Atukunda et al., 2021; FAO et al., 2020). According to FAO et al. (2020), the current COVID-19 pandemic may lead to about 83-132 million additional malnourished people in 2020. The impact of the pandemic coupled with factors such as the unprecedented activities of locusts in East Africa presents crucial challenges for food production, distribution, and access (FAO et al., 2020).

2.4.1 Food insecurity in Ghana

There has been some progress in addressing hunger and malnutrition in Ghana. For example, Ghana among four other African countries (Rwanda, Angola, Malawi) were acknowledged to have met the MDG target in 2013 (FAO, 2015). Also, The Global Hunger Index (GHI), a standard statistical measure of multiple facets of hunger and malnutrition indicated Ghana had reduced hunger by roughly 68% between 1990 and 2013 (FAO, ECA, et al., 2020; AfDB, 2014). Nonetheless, comprehensive food insecurity vulnerability studies by the World Food Programme (WFP), Government of Ghana and other stakeholders in northern Ghana indicate a significant local variation in pervasiveness and precariousness of hunger in Ghana. Studies such as (Atuoye et al., 2019; Kuuire et al., 2013; Nyantakyi-Frimpong, 2013; Luginaah et al., 2009) have acknowledged the widespread and severe food insecurity in northern Ghana and the concomitant problems, depicting that national statistics may be over-generalized and do not reflect variations at local levels.

For example, northern Ghana accounts for over half of the food insecurity in Ghana. (Ministry of Food and Agriculture, 2020). Food insecurity in northern Ghana is primary attributed to the underlying climate stress such as droughts, high temperatures, and erratic rainfall that is counterproductive to food production (Antwi-Agyei et al., 2018; Armah et al., 2011). In addition, the widespread and devastating food insecurity in northern Ghana is exacerbated by the underlying high impoverishment, unstable food prices, weak political governance, high unemployment and low levels of education (Kuuire et al., 2013; Yaro, 2013; Yaro & Hesselberg, 2010; Luginaah et al., 2009).

The food insecurity situation in northern Ghana is partly due to an increase in food prices. For example, there has been an increase of 2.05% in the price of maize in the Tamale market, the largest in northern Ghana (Ministry of Food and Agriculture, 2020). The prices of other crops such as local rice, imported rice and cassava increased by 26.94%, 8.69% and 88.58%, respectively in Tamale (Ministry of Food and Agriculture, 2020). However, there has been a decrease or a relatively low increase in food prices in southern Ghana (Ministry of Food and Agriculture et al., 2020). Also, poverty rates are highest in northern Ghana. For example, poverty rates in Upper East Region, Northern Region and Upper West Region increased from 44%-55%, 50%-615 and 70%-71% from 2012-2016, respectively (Ghana Statistical Service, 2019). The increases in food prices coupled with the high poverty rates in northern Ghana indicate that households may be unable to afford food and will likely transition to food insecurity. In northern Ghana, structural gender norms and values continue to exacerbate poverty and food insecurity (Nyantakyi-Frimpong, 2021; Kansanga et al., 2019; Yaro & Hesselberg, 2010; Luginaah et al., 2009). Thus, ensuring equal access to resources and opportunity presents a vital prospect towards eradicating hunger and malnutrition (FAO et al., 2020).

2.5 Theoretical framework

The thesis draws insights broadly from theoretical constructs in political ecology. According to Watts & Peet (2004), political ecology is focused on the study of power relations, social struggles and political conflicts in the appropriation of ecological and natural resources. The genesis of political ecology can be traced back to the 1980s when scholars such as Watts (1983) and Blaikie & Brookfield (1987) were primarily influenced by environmentalism and its emphasis on overpopulation and the carrying capacity of the earth (Perreault et al., 2015). Earlier study locations of political ecology were mainly in the global south, where decolonization (revolutionary and peaceful) transformed the landscape and political boundaries (Collins, 2008; Watts & Peet, 2004). Perreault et al. (2015) argue that political ecology is somewhat unrestrained and continues to evolve into new spaces, themes, and scales. Consequently, the coherence of political ecology is not in a specific research topic (e.g., deforestation, resource governance, agrarian livelihoods, resource conflicts) nor scale (e.g., household, community, landscape, rural, urban). Political ecology conceptualizations are based on a critical dedication to social theory and post-positivism to understand nature and the production of knowledge about our physical and social environment (Perreault et al., 2015). Given its broad nature and appeal, a pluralism of methodologies have been used for research informed by political ecology conceptions. These methodologies include both quantitative and qualitative methods (Perreault et al., 2015). Another critical facet of political ecology is its commitment to social justice and political change among marginalized groups such as indigenous people, religious minorities, women, poor and smallholder peasant farmers (Kansanga et al., 2019; Nyantakyi-Frimpong, 2019a; Collins, 2008). Therefore, political ecology is a cumulation of theoretical, methodological, and political commitments in studying nature and human interactions with nature. In the next paragraphs, I discuss specific theories, frameworks and models within political ecology used in this thesis. These include political ecology of vulnerability, risk, hazards, resilience, and

feminist economics (specifically intra-household bargaining and resource allocations). Therefore, this is research is also informed by theoretical constructs on resilience and vulnerability.

The origin of resilience is in ecology, with the earliest studies exploring predator-prey relationships and the implications for the stability of ecosystems (May, 1972; Holling, 1973). Resilience is also an evolving concept. Earlier conceptualization of resilience concentrated on single equilibrium systems with fixed capacities (Folke, 2006). However, the conceptualization progressed to encompass multi-stable systems (Folke, 2006; Holling, 1973). Resilience has now advanced to include social and ecological systems, termed socio-ecological resilience (Adger, 2000). Socio-ecological resilience is focused on the interaction of multiple factors such as socio-economic, political, cultural and ecological factors in shaping systems' ability to adapt, learn, self-organize and metamorphosize amid perturbations (Carpenter et al., 2012; Folke, 2006). According to Jones et al. (2018), socio-ecological resilience depends on the capacity of a system to prepare, recover, and adapt to anticipated or current environmental stressors. Therefore, the concept of adaptation is critical in resilience studies.

In the climate change discourse, adaptation broadly refers to the process of adjusting to climate shocks to lessen vulnerability and enhance resilience (IPCC, 2014). Adaptation in smallholder communities is mainly autonomous. However, adaptation initiatives and policies tend to focus on structured adaptation strategies (Antwi-Agyei et al., 2014). The emphasis on structured adaptations through “technological fixes” has proven ineffective in improving resilience to climate change in rural and agrarian communities (Antwi-Agyei et al., 2018; Adger et al., 2003). An emphasis on harnessing local autonomous adaptations is crucial in reducing vulnerability, given that vulnerability is a differentiated experience among smallholder farmers (Nyantakyi-Frimpong, 2019c; Adger et al., 2003). There are multiple identities and intersectionalities in smallholder communities that lead to differences in susceptibility to climate change stressors among the same or similar people (Nyantakyi-Frimpong,

2019c; Perreault et al., 2015).For example, though women are generally more vulnerable to climate change impacts, vulnerability among similarly marginalized women may differ due to intersecting factors such as marital status, type of marriage, number of children and spouse (Kansanga et al., 2019). The gendered nature of vulnerability to climate change and food insecurity among smallholder households calls for the use of nuanced approaches such as feminist economies and intra-household bargaining.

Feminist economies and household bargaining theories are crucial in exploring the relationship between intra-household decision-making arrangements and food security. Intra-household bargaining is essential in understanding the mechanisms of power relations in allocating household resources (Fiala & He, 2017; Agarwal, 1997). Unitary (based on a sole decision maker) and non-unitary (based on multiple decision makers) models are used to explain the mechanism of decision making and resources allocated in the household (Agarwal, 1997; Haddad et al., 1997). Unitary intra-household decision-making postulate a single decision-maker for the household. This is based on the premise that the household has a somewhat aggregated interest and preferences as a unit and a single household member (i.e., household head) can make all decisions on behalf of the household (Manser & Brown, 1980). The assumption of a single decision maker in unitary intra-household bargaining represents an oversimplification of the complexity of the households as a decision-making unit. According to Lundberg & Pollak, (1993), individual household members have different interests and preferences as well as different experiences and knowledge base. Unitary intra-household bargaining mostly reflect the patriarchal system in SSA, where gender norms posit that decision making is the sole role of the male household head (Kansanga et al., 2019; Nyantakyi-Frimpong, 2019b).

On the other hand, non-unitary intra-household bargaining frameworks (cooperative and non-cooperative) acknowledge multiple decision makers in the household (Mohapatra & Simon, 2017; Doss,

2013; Agarwal, 1997). In cooperative bargaining, the negotiation power of each household member is a function of their fallback position—an external option that indicates how better off they will be in a non-cooperative scenario (Doss, 2013). In cooperative bargaining models, household members negotiate and reconcile their different preferences to attain 'Pareto efficiency' (Doss, 2013; Agarwal, 1997). The benefit each household member drives from the household negotiation is based on their bargaining power. According to Sen (1987), perceived contribution and interest responses are also critical factors to consider in a household negotiation. Perceived interest and contribution responses are shaped by structured gender roles and responsibilities (Agarwal, 1997; Haddad et al., 1997). In smallholder communities, structural gender norms limit women's fallback position and, consequently, their participation in decision-making (Kansanga et al., 2019; Nyantakyi-Frimpong, 2019b; Carney, 2004). While gender norms are fast evolving in smallholder communities in Ghana, women's participation in decision making remains limited. Therefore, this study examined the association between intra-household decision-making arrangements and food security among smallholder farmers.

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Chapter 3

3 Methods

3.1 Introduction

This chapter explains the study methodology. The chapter provides background to the study context, describes the study design and data collection methods. This chapter further discusses the sampling techniques and data analysis methods utilized in this thesis. Though the individual manuscripts integrated into this thesis contain individual methods section, this section provide a comprehensive discussion of all implemented methods in the research.

3.2 Study design

The study used a quantitative study design because the main aim was to examine the association between (i). livelihood diversification strategies and climate change resilience and (ii). Intra-household decision making arrangements and food security. The primary data collection tool was, therefore a survey. Given the nature of the research questions, quantitative research design was the most appropriate method to achieve the research objectives. Quantitative research designs explain phenomena by collecting numerical data, which are analyzed using mathematical approaches (Creswell, 2009). Also, quantitative methods were instrumental in this study because the study seeked to objectively generalize findings to the broader population of smallholder farmers in Ghana and similar context in SSA.

It is essential to point out that this study is underpinned by post-positivist ontology and epistemologies. Post-positivism acknowledges the flaws of traditional positivism, however, do not entirely reject realism. The fundamentals of positivism emphasize that researchers cannot observe the phenomena from their world as totally disinterested and objective individuals (Miller, 2000; Sukamolson, 2007). The genesis of post-positivism is from the premise that scientific knowledge cannot be acquired devoid of the individual researcher's emotions, interests, and biases (Sukamolson, 2007).

Contrary to traditional positivism, post-positivism posits that absolute certainty in research is unattainable (Clark, 1998). According to Sukamolson (2007), rather than an overemphasis on certainty in research, social scientific inquiries should focus on confidence — the reliability of findings and how well outcomes are estimated. Therefore, in this research, I endeavour to approximate reality as best as possible while also recognizing that my subjectivity may shape the findings of this research. The purpose of this research is not to establish truth on climate change resilience and food security in semi-arid Ghana but to represent it as best as possible.

3.3 Data collection and sampling

Data collection was done between July to August 2019. The survey team constituted three researchers and six local research assistants. First, the 6 research assistants were selected based on specific criteria such as research experience, proficiency in local languages and familiarity with the study context (i.e., the Upper West Region). Two research assistance were assigned to each of the three study districts (Wa West, Lawra, and Nadowli-Kaleo). The research assistance had to have resided in the assigned district. This was to ensure familiarity with the study context and high proficiency in the native language. Each of the three researchers supervised two research assistants in each of the districts. Though the research assistants were selected partly based on research experience, they were trained intensively for 5 days on the survey instrument and ethics and safeguarding protocols per ethical guidelines of the University of Western Ontario Non-Medical Research Ethics Board. Thus, the research assistants signed an agreement of confidentiality to protect the privacy and anonymity of the study participants. Prior to the data collection and as part of the training, the survey questions were role played and extensively discussed to ensure the meaning of the questions was consistent across local languages and districts. The research assistants sought oral consent from participants in their local languages. Only participants who consented to participate in the survey were asked further questions. It is also important to note that the

research team first consulted community leaders (i.e., opinion leaders) to inform them about the purpose of the study and introduce the research team to them.

To best answer research questions, the study used a household survey that particularly targeted primary farmers of each household to respond on behalf of the household. The Farmer Livelihood and Agricultural Production (FLAP) survey included questions about household demographics, agricultural production, household food security, household expenditure, livelihood activities, gender relations, adaptive capacity and resilience. A multi-stage sampling method was used to select 1100 smallholder farmer households. The sample size of the research was determined using.

$$n = \frac{\mathrm{N}}{1+\mathrm{N}(e)^2} = \frac{702110}{1+702110(0.03)^2} = \frac{702110}{1+702110(0.0009)} = 1{,}110 \quad \ldots\ldots \mathbf{1}$$

Where 'n' is the sample size, 'N' is the population size,

and 'e' is the margin of error or level of precision (Israel, 1992).

Using the simplified formula above, a sample of 1,100 is representative of the population of Upper West Region (702,110) at a precision level of 0.03. First, three districts (Wa West, Lawra, and Nadowli-Kaleo) were selected using purposive sampling. These districts were specifically selected because a high proportion of their populations are impoverished smallholder farmers. For example, the Wa West district ranks number one as the poorest district in Ghana, while Lawra and Nadoeli-Kaleo rank 13th and 17th poorest districts (Ghana Statistical Service, 2019). Therefore, amid increasing climate stressors and high impoverishment, smallholder farmers in these districts are particularly vulnerable to food insecurity and other climate change stressors. Next, the participating smallholder communities in each district were selected using a simple random sampling technique. Finally, a systematic sampling technique was used to select household units by selecting every fifth house where the research team first enters the community/village.

The study used the Household Food Insecurity Access Scale (HFIAS) to collect data on household food security outcomes in the Upper West Region. HFIAS captures the perceptions of households regarding the prevalence of food insecurity among household members. HFIAS presents a comprehensive measure of household perceived food security outcomes. The HFIAS has been widely used to measure food security in rural context (see Dejene & Cochrane, 2021; Mohamed Nour & Abdalla, 2021; Pandey & Bardsley, 2019; Atuoye et al., 2019). HFIAS includes questions on uncertainty over the availability of food, food deficiency in quantity and quality, reduction in food intake, indignity in obtaining food (Coates et al., 2007). Some of the questions that were used in computing the HFIAS included 'In the past 4 weeks, were you ever worried that you may not have enough food in your household? In the past four weeks did you or any household member have to eat a limited variety of foods due to a lack of resources? In the past four weeks was there any household member who had to eat some foods that you really did not want to eat because of a lack of resources to obtain other types of food? In the past four weeks was there any household member who ate fewer times per day because there wasn't enough food? In the past four weeks was there ever no food to eat of any kind in your household because of lack of resources?'. Participants rated how often they had experience any of the above in the past 4 weeks preceding the survey by indicating the following options: rarely (1-2 times), sometimes (3-10 times) and often (more than 10 times).

Climate resilience was a self-reported measure. Participants were asked 'how would you rate your ability to handle flood/drought/ erratic rain related stress?' According to Jones & Tanner, (2015), households have a good understanding of the mediators of their ability to anticipate, recover, and adapt to climate change stressors. More so, the lack of quality secondary data in rural context makes the use of objective measures of climate change resilience particularly challenging (Jones & Tanner, 2015; Oriangi et al., 2020).

3.4 Data analysis

The data collected was processed in R-Studio version 1.4. 1103. Prior to data analysis, the data was screened for data entry and coding errors. I appropriately cleaned all these errors to prevent bias and to ensure the credibility of statistical estimates. A detailed description of the analytical approaches are provided in the individual manuscript. This section therefore provides a broad description of the analytic methods employed in this dissertation. The dependent variables (i.e., climate change resilience and food security) are both ordered outcomes. Thus, I used the proportional odds logistic regression. Proportional odds logistic regression is an extension of the binary logistic regression to instances where the outcome variable has ordered categories (Brant, 1990). For the first manuscript, I used the proportional odds logistic regression to examine the relationship between livelihood diversification strategies and resilience to climate change in semi-arid Ghana. The outcome variable was resilience to climate change, which had three levels (i.e., good, satisfactory, and poor). In the second manuscript, I used the proportional odds logistic regression to examine the association between intra-household decision making arrangement and food security in semi-arid Ghana. The other outcome variable was food security with four ordered levels (i.e., severely food insecure, moderately food insecure, mildly food insecure, food secure).

Ethical approval for this research was received from the University of Western Ontario Non-Medical Ethics Research Board. Safeguarding the privacy, confidentiality, and anonymity of participants is a critical part of the research process. Therefore, as per the protocols of the University of Western Ontario Non-Medical Ethics Research Board, the purposive of the study was explicitly communicated to the study participants. The researchers unequivocally informed the study participants that the study does not offer any direct benefits to them. Also, researchers informed participants that they would not incur any direct cost aside from the time spent discussing their livelihoods with the researchers. However,

participants were informed that the study is an opportunity for them to express their concerns as farmers. Participants were also informed that the research may benefit them indirectly, as findings from the study may be shared with local, national, and international institutions. The findings may help inform initiatives by such organizations to improve food security and build resilience to climate change. The researchers unequivocally communicated to participants that their privacy, confidentiality, and anonymity is guaranteed and that they have the right to withdraw from the study at any time.

3.5 Rigor

Throughout the study (study design, data collection and analysis), appropriate measures were taken to ensure the robustness of results from statistical estimates. Robustness of findings is essential for the reliability, validity, and generalizability of the study findings. During the study design, survey questions were made very simple and easy to interpret and translated to the respective local languages. However, the comprehensibility of questions was not comprised through the translation. Research Assistants were recruited based on prior experience with data collection, level of education (i.e., tertiary education), and proficiency in local languages. That notwithstanding, they were trained comprehensively on the survey instrument as well as ethical and safeguarding protocols through a pretest of the survey instrument. The researchers consistently monitored research assistants to ensure that the data collected is of high quality. The sample was proportionately distributed among the three selected districts (i.e., Lawra = 295, Nadowli = 367, Wa West = 438) based on their populations. The total sample (n = 1100) was also large enough for generalization across smallholder farmers in northern Ghana and similar context in SSA.

3.6 Researcher positionality

A researcher's positionality in social science research is important for data collection and interpretation. Doing research in an individual's native community may facilitate access to information, improve understanding of the contextual issues and ensure cultural sensitivity. As a Ghanaian born in the Northern Region of Ghana with deep seated lived experiences in the region, I am a native of northern Ghana and an insider for that matter. However, though northern Ghana has numerous cultures in common, there are different ethinc groups with different languages and cultures in the region. For example, the study was particularly conducted in the Upper West Region with native languages (e.g. "Dagari", "Sisaala") that are slightly different from my native language(i.e. "Dagbani") and cultures that I am not entirely familiar with. Notwidthstanding the similarity in physical and human environment in northern Ghana, I may be considered an outsider because I am not particularly a native of the Upper West Region.

3.7 Conclusion

This chapter has elaborated on the methodological design of the research. The chapter outlined the link between the methods in the two manuscripts integrated into this thesis. The chapter further described the study design, data collection tools, sampling, and data analysis. Finally, this chapter highlighted the key measures instituted throughout the research to ensure validity, reliability, generalization, and overall robustness of findings.

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Chapter 4

Livelihood Diversification Strategies and Resilience to Climate Change in Semi-arid Northern Ghana

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4: Livelihood Diversification Strategies and Resilience to Climate Change in Semi-arid Northern Ghana

Climate change threatens the livelihoods of smallholder farmers in the Global South. In the semi-arid regions of Ghana, where over 73% of the population is engaged in smallholder agriculture, climate-induced food insecurity is of major concern. Livelihood diversification is acknowledged to have the potential to improve climate resilience in smallholder farming systems through risk spreading. That notwithstanding, little is known about the links between livelihood diversification strategies and climate resilience in such vulnerable settings. Drawing data from a cross-sectional survey with 1100 smallholder households in semi-arid northern Ghana, this study contributes to the literature by examining the association between livelihood diversification and climate resilience. Findings from logistic regression analysis revealed that smallholder farming households that practiced only farm diversification (OR = 3.95; $p \leq 0.05$) and a combination of both farm and nonfarm diversification (OR = 5.77; $p \leq 0.01$) had significantly higher odds of reporting stronger resilience to climate change compared to those who did not employ any diversification strategy. The study further revealed that land preparation techniques, source of climate information and religion were significantly associated with smallholder household farmers' perceived climate change resilience. These findings point to the need for agricultural policies to promote both farm and nonfarm livelihoods as complementary risk-spreading strategies. Exploring the synergies between farm and nonfarm livelihoods may prove beneficial in semi-arid agrarian contexts. In doing so, critical contextual dynamics such as source of farm power and sources of climate information must not be overlooked.

4.1 Introduction

Climate change is now recognized as a global emergency and societies worldwide are taking urgent actions to adapt and build resilience (Intergovernmental Panel on Climate Change [IPCC], 2014; Ludi et al., 2012). Climate change resilience generally refers to a system's ability to absorb and recover from climate-related stresses (Adzawla et al., 2019; Holling, 1973; Folke, 2006). According to the IPCC, smallholder farmers in Sub-Saharan Africa (SSA) are particularly vulnerable to climate change because of the extensive reliance on rainfed agriculture and limited capacities to adapt (IPCC, 2014). Climate projections for SSA show that increasing temperatures and erratic rainfall patterns will likely decrease crop production significantly, which has critical consequences for food security and smallholder livelihood systems (Dumenu & Obeng, 2016; IPCC, 2014; Boko et al., 2007). The IPCC (2014) acknowledges that current adaptation strategies in SSA are insufficient to ensure agricultural systems' resilience to climate change-related stress and risks. Therefore, it is vital to explore strategies for improving livelihood adaptations and resilience among highly vulnerable populations across SSA.

Empirical research in the Ghanaian context demonstrates low resilience to climate change among vulnerable smallholder farming households (Appiah et al., 2018; Assan, 2014; Nyantakyi-Frimpong, 2013). About 73% of households in semi-arid northern Ghana are smallholder farmers who typically cultivate an average land of about 5 acres (Dapilah & Nielsen, 2019; Ghana Statistical Service [GSS], 2019). Smallholder farmers in semi-arid northern Ghana depend primarily on rain-fed agricultural systems (Kuuire et al., 2013; Dapilah & Nielsen, 2019). With increasing climate variability, the region is vulnerable to climate-induced food insecurity, with about 30% of households already being food insecure (Nyantakyi-Frimpong, 2013; Biederlack & Rivers, 2009). There have been efforts made by the Government of Ghana and

other global partners to enhance food security, climate change resilience, and reduce poverty. Such efforts include climate-smart agricultural interventions launched by the Food and Agriculture Organization (FAO) in collaboration with the Government of Ghana to increase resilience to climate change (FAO, 2015). A relatively recent major policy intervention is the Planting for Food and Jobs initiative that seeks to improve climate change resilience and food security by facilitating farmers' access to inputs and extension services (Ministry of Food and Agriculture [MoFA], 2019; Tanko et al., 2019). Despite these policy interventions, about 1.2 million people in Ghana are still food insecure, with approximately 60% in semi-arid northern Ghana (MoFA, 2019). Among the diverse factors that explain the disproportionate food insecurity situation in northern Ghana, climate variability is a central driver (Baada et al., 2020; Dapilah & Nielsen, 2019). These underlying dynamics demonstrate the need to explore strategies for building farmers' resilience to climate change as a pathway to improving food security.

Livelihood diversification and migration are acknowledged as key adaptation strategies in response to climate change in smallholder farming contexts (e.g., see Adzawla et al., 2019; Asravor, 2018; Bezner Kerr et al., 2016; Makate et al., 2016; Ellis, 1998). In rural contexts, farmers' response to climate change is primarily shaped by the perceived impacts of climate change. Climate change perceptions are based on indigenous knowledge systems gained through longstanding experiences of rainfall patterns and temperatures and traditional climate indicators (Nyantakyi-Frimpong and Bezner-Kerr, 2015; Orlove et al., 2010; Tschakert, 2007). In semi-arid Ghana, smallholder farmers have reported climate change stress, including erratic rainfall, increasing temperatures and prolonged periods of droughts (Lawson et al., 2020; Dapilah et al., 2020). In response, smallholder farmers in semi-arid Ghana diversify their livelihoods as a form of adaptation to ensure livelihood security (Niehof, 2004; Barrett et al., 2001; Ellis, 2000).

Recent literature demonstrates the centrality of livelihood diversification in adapting to climate change in semi-arid Ghana (see Lawson et al., 2020; Dapilah et al., 2020).

Generally, livelihood diversification entails engagement in diverse socio-economic activities (Ellis, 1998). In smallholder farming settings, livelihood diversification is an essential risk-spreading strategy. The fundamental rationale for livelihood diversification is that multiple alternative livelihood activities (e.g. petty trading, hunting, and migration) can provide fall back for the households in the event that the primary source of livelihood fails (Loison, 2015; Ellis, 1998). There is limited research on the relationship between livelihood diversification strategies and resilience to climate change, especially among smallholder farmers in semi-arid contexts. Haggblade et al. (2010) acknowledge that the relationship between livelihood diversification and climate change resilience is complex and requires a more nuanced assessment. Discussions on livelihood diversification in smallholder farming contexts mainly concentrate on diversification outside the agricultural sector, with less emphasis on opportunities within farm livelihoods in smallholder rural communities and synergies between these two livelihood strategies (Tsiboe et al., 2016; Senadza, 2014; Dary & Kuunibe, 2012; Owusu et al., 2011). This study contributes to the literature by exploring farm and nonfarm livelihood diversification strategies as complementary activities in facilitating resilience to climate shocks among smallholder households.

4.2 Theoretical framework

This paper draws insights from the literature on resilience, vulnerability and adaptation to explore the association between livelihood diversification and farmer responses to climate change. Resilience as a concept originated from ecology around the 1960s and early 1970s

(Folke, 2006). The earliest studies on resilience focused on predator-prey relationships and the implications for ecological stability (Folke, 2006; May, 1972; Holling, 1961). This conceptualization emphasized a single equilibrium with fixed capacities of ecological systems (Folke, 2006). The conceptualization of resilience was further extended to a multi-stable state which focused on the resilience of systems not limited to a single equilibrium and stability, but rather on variability and dynamism of ecosystems (Folke, 2006; Holling, 1961). Discussions of resilience moved beyond ecological resilience to include social resilience. Social resilience emphasized the capacity of human societies to withstand external shocks from environmental variability (e.g. climate change and variability) and other socio-economic perturbations (Adger, 2000). Folke (2006) argued that resilience is not limited to the ability to withstand disturbances but includes the opportunities presented by disturbances such as the rejuvenation of systems and the emergence of new avenues for continual growth. Socio-ecological systems, therefore, incorporate adaptation, learning and self-organization in addition to the ability to withstand shocks (Folke, 2006). Carpenter et al. (2001) highlighted three main components of socio-ecological resilience: (i) the amount of shock a system can absorb and remain functional, (ii) the level to which the system is capable of self-organization, and (iii) the degree to which the system can increase its capability for continual learning and adaptation. Resilience can be explored at different levels including individual, household, community, and national levels (Folke, 2006; Speranza et al., 2014).

In this study, we conceptualize smallholder farmer household resilience as a social-ecological outcome involving the interaction of complex ecological, socio-economic, political and cultural factors (Folke, 2006; Holling, 1973). Socio-ecological frameworks and indices that are widely used to measure climate resilience are based on three fundamental capacities: capacity

to prepare, capacity to recover and capacity to adapt (Jones et al., 2018; Jones & Tanner, 2015). First, a household's capacity to be prepared emphasizes the household's ability to anticipate and reduce the impacts of climate change and variability. Second, a household's capacity to recover is the ability to absorb shocks (e.g., drought, floods, and other extreme climate events) and remain functional. Finally, a household's capacity to adapt is the ability to adjust to stress using diverse livelihood activities (Jones & Tanner, 2015; Folke, 2006).

Adaptation is an integral part of climate change resilience. Adaptation has evolved over the years and is conceptualized differently in various disciplines (Thornton & Manasfi, 2010; Smit & Wandel, 2006). Adaptation has its origins in biology, where it broadly refers to the development of genetic or behavioural features to enable an organism to evolve and cope with environmental stress (Thornton & Manasfi, 2010). In the social sciences, adaptation refers to the process by which a person, household or community adjusts their social, economic and cultural practices in response to environmental shocks (Smit & Wandel, 2006). Integrating biological and social/cultural adaptation, the IPCC defines adaptation as adjusting to climate shocks to reduce vulnerability and increase resilience (IPCC, 2014). Thornton & Manasfi (2010) argue that there is an emphasis on 'planned' adaptation, with much neglect of 'autonomous adaptation' at local levels in the climate discourse. Thornton & Manasfi (2010) raise critical questions about the emphasis on what individuals, households and communities ought to rationally do to reduce vulnerability to climate stress. Adaptation through 'technological fixes' has associated economic and environmental shortfalls (Adger et al., 2003). Therefore, Adger et al. (2003) suggest that it is central to understand successful local and traditional adaptation strategies among vulnerable groups in the Global South, such as smallholder farmers who face the most significant risk of climate change-related perturbations.

Vulnerability is a differentiated experience given that multiple intersectional identities may result in unequal susceptibilities among similarly marginalized and exposed populations (Nyantakyi-Frimpong, 2019; Perreault et al., 2015; Nightingale, 2011). For instance, a poor household may have influential members (e.g. community leaders and or educated persons) who likely have access to early warning information, thereby facilitating their capability to be proactive in response to climate shocks, making such households more resilient (Kerr et al., 2016; Folke, 2006). Household vulnerability is counterbalanced by household capabilities, including preparedness, response and recovery, broadly termed resilience (Wisner et al., 2012; Cutter et al., 2003).

In smallholder contexts, livelihood adaptation through diversification is increasingly promoted to reduce climate vulnerability (Scoones, 1998). The motives for diversifying livelihoods outside primary subsistence farming can be primarily categorized into 'pull' and 'push' motives (Ellis, 2000b). With regard to ‘pull’ motives, households may diversify their livelihoods to take advantage of other lucrative ventures that could increase their household income (Haggblade et al., 2007). However, ‘push’ motives for diversification are mainly due to crucial needs for survival. According to Scoones (1998), ‘push-motivated’ livelihood diversification may help cope with short-term stress or long-term adaptation and either to a wide range of shocks or specific shocks. Amid the climate emergency and the devasting effects on smallholder livelihoods such as crop and market failures, diminishing returns of land and/or labour, and food insecurity, smallholder farmers are often compelled to diversify their livelihoods for survival (Atuoye et al., 2019). Livelihood adaptation strategies are concurrent processes that ought to be conceptualized holistically (Thornton & Manasfi, 2010). Smit et al. (2000) presented a practical conceptualization of livelihood adaptation based on (i) who/what has

to adapt? (ii) What do they have to adapt to? and (iii) how do they adapt? In this context, the 'who' refers to the smallholder farmer, 'what' they have to adapt to is climate shocks (drought, flood, erratic rainfall) and 'how' they adapt is through livelihood diversification. Livelihood diversifications are broadly categorized by sector (farm/agricultural and nonfarm/non-agricultural), by function (self-employment and wage employments) and by location (on-farm and off-farm) (Barrett et al., 2001; Ellis, 1998; Saith, 1992). Detailed descriptions are shown in Table 4. 1.

Table 4. 1: Classifications of smallholder household livelihood diversification strategies.

Classification	Category	Description
By Sector	Farm (Agricultural)	Includes livelihood activities that involve the production of unprocessed crops (i.e., outside primary subsistence crop production), livestock, poultry, vegetable gardening, fish and gathering natural products from farms. Sales of farm produce are considered part of farm diversifications. This involves the cultivation of high-value crops that smallholder farmers do not typically cultivate.
	Nonfarm (Non-Agricultural)	This comprises all livelihood activities outside primary agricultural production. This includes small-scale mining, formal jobs, petty trading, agro-processing, trading in agricultural unprocessed produce and animals, grocery stores, and remittances.
By Function	Wage employment	This classification is centered on the relationship between employer and employee. In this category, the employee trades their labour to the employer for a wage.
	Self-employment	Involves the utilization of one's labour as opposed to selling it to another person. Individuals earn an income themselves through the activities they engage in.
By Location	On-farm	Livelihood activity takes place on the farm. This may include; crop and livestock production, fishing, hunting, gathering shea fruits and other natural edible or medicinal products.

Off-farm	This includes livelihood activities that take place entirely outside the farm (as a place). This also includes all nonfarm livelihood activities

Notes: This table is adopted from Barrett et al. (2001); Ellis (1998); Haggblade et al. (2010); Loison (2015). The classification by sector uses standard national accounting systems. Classification by location is a function of where the livelihood takes place and classification by function is centered on the compensation of labour (Loison, 2015).

In the context of smallholder communities, categorization of livelihood diversification by sector presents a more comprehensive and clear distinction between primary agricultural production and non-agricultural production livelihoods as it uses classifications based on the standards of national accounting systems (Loison, 2015). Therefore, we used the categorization of livelihoods by sector to understand the role of farm and nonfarm livelihoods in smallholder resilience to climate change.

4.3 The study setting

Semi-arid northern Ghana is part of the Guinea Savanna ecological zone of the country, comprising the Northern, Upper East, Upper West, Savanna, and North East administrative regions. The Upper West Region was used as a case study (Figure 4.1). Upper West Region has a total population of 702,110 and covers a land area of 18,476 km^2 (GSS, 2019). The main economic livelihoods of people in Upper West Region are highly dependent on agricultural activities. About 73% of the economically active population are engaged in diverse livelihood activities in the agricultural chain (GSS, 2013). The region is the most impoverished in Ghana, partly due to political neglect in development since the colonial era and poor education (Yaro, 2013; Songsore, 2003).

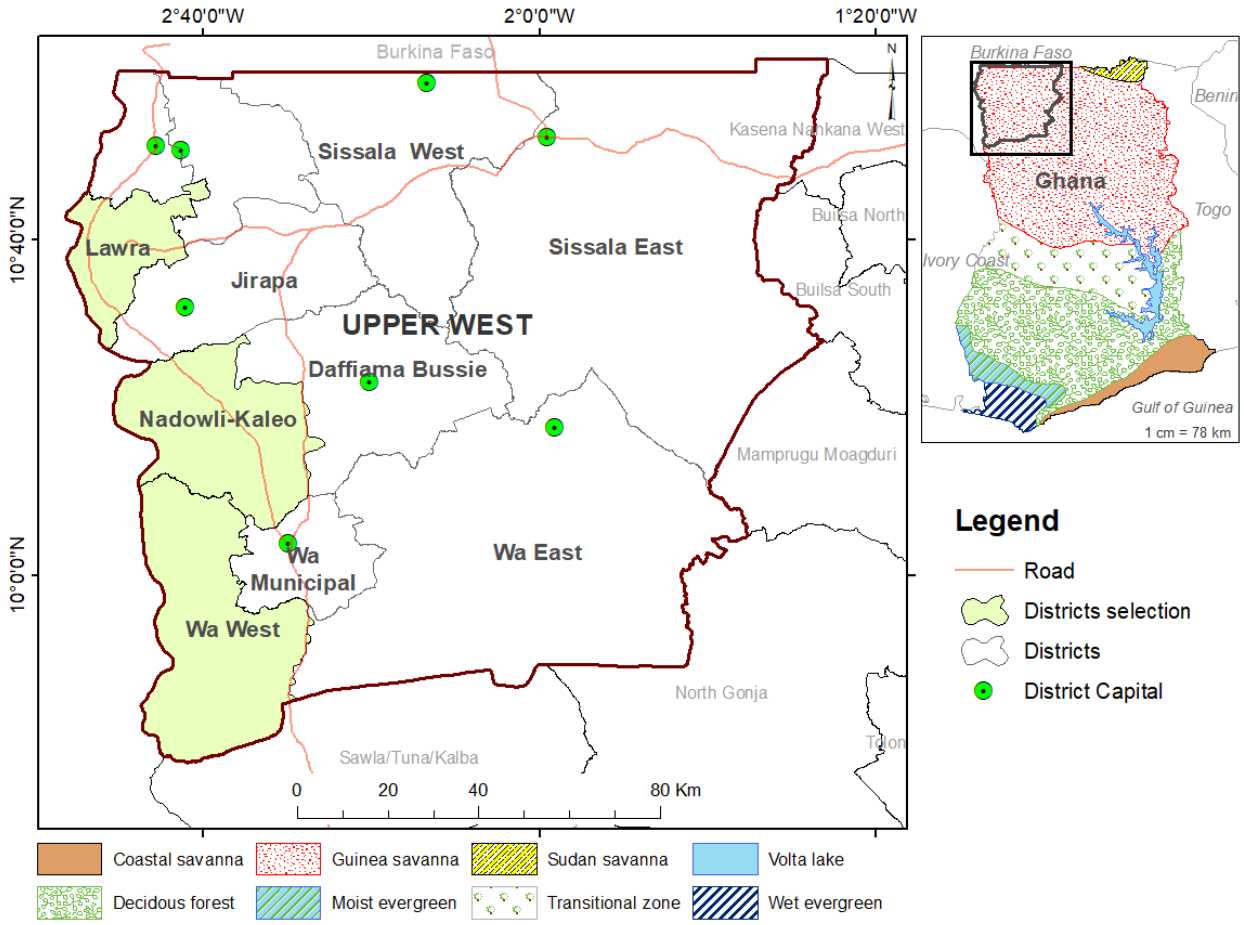

Figure 4. 1: Map of Upper West Region

The Upper West Region is the driest part of Ghana and has a single cultivation season per year. The region is projected to become drier as global temperatures increase and precipitation decrease (Riede et al., 2016). The Upper West Region typically has two seasons, the rainy season from April to October and the dry season from November to March. The region has a mean minimum and maximum precipitation of 840mm and 1400mm, respectively (Ghana Statistical Service, 2013). However, annual precipitation which tends to be concentrated from June-September has become irregular with shifting rainfall patterns (Adiku et al., 2017; Ghana

Statistical Service, 2013). The shifting pattern in precipitation is characterized by torrential downpour, which facilitates surface run-off and impedes soil moisture retention (Ghana Statistical Service, 2013). The region has an average temperature of about 28º C, with a temperature increase of about 1.7º C in the last five decades and is projected to increase by 3º C by 2050 (Adiku et al., 2017). Evapotranspiration in the region is estimated to have increased by 22% within three decades, affecting soil moisture retention (Adiku et al., 2017). The erratic rainfall patterns, increasing temperatures, low soil moisture retention and droughts present a significant challenge to smallholder farming in the region (Adiku et al., 2017; Ghana Statistical Service, 2013). The changing environmental conditions result in increased migration to the Brong Ahafo Region, where evidence now suggests increasing pressure on farmlands in that region (Kuuire et al., 2013; Luginaah et al., 2009). It is imperative to understand how farmers in the Upper West region sustain their livelihoods for potential policy intervention, amid climate change and variability.

4.4 Methods

4.4.1 Data collection

This paper draws data from the Farmer Livelihoods and Agricultural Production (FLAP) cross-sectional survey conducted in the Upper West Region from July to August 2019. A multistage sampling technique was used to sample smallholder farmers (n = 1100). Purposive non-probabilistic sampling was first used to select three districts (Nadowli-Kaleo, Lawra, and Wa West) in the region. Simple random sampling was used to sample communities/villages in each of the three districts. Systematic sampling was further used to select household units in the study area. Every fifth house was selected for the survey. The survey covered thematic areas of

smallholder farmers livelihoods including; smallholder demographics, agricultural production, household expenditure, housing, household assets, access to credit, livelihood activities, gender relations, food security, adaptive capacity and perceived climate resilience. Ethical approval was granted by the Non-Medical Research Board of the University of Western Ontario, Canada.

4.4.2 Measures

The dependent variable (i.e., climate change resilience) is derived from questions where smallholder farming households rated their ability to anticipate, adapt and recover from climate-related stresses (i.e., drought, flood, erratic rainfall, storm surge) that they experienced in the last 12 months preceding the survey. Smallholder households were required to rate their ability to withstand climate shocks and stress by indicating as either 0 = poor, 1 = satisfactory and 3 = good. We, therefore, used smallholder households' self-reported measure of resilience to climate change. Notwithstanding the wide use of objective resilience measures using secondary data, we used a subjective measure of resilience using primary survey data. Jones & Tanner (2015) argue that households have a good understanding of the factors that contribute to their ability to anticipate, recover and adapt to stress. Also, in many developing countries, a lack of secondary data, particularly in rural settings (Oriangi et al., 2020; Jones & Tanner, 2015), means that using objective measurements of resilience can be challenging. Jones & Tanner (2015) argue that aside from the data limitations, objective measurement creates room for bias in the choice of indicators and the inability to measure less tangible processes that affect household resilience and adaptation. Consequently, subjective measurement of perceived household resilience has been used in measuring resilience in rural contexts (Oriangi et al., 2020; Jones et al., 2018; Jones & Tanner, 2015).

The focal independent variable is livelihood diversification. A preset list of the common livelihood strategies in the study context were outlined in the survey and respondents were asked whether they engaged in each of these livelihood activities or not. We identified 17 different livelihoods which smallholder farmers were engaged in; petty trade, remittance, formal salary, fishing, small-scale mining, livestock trading, cash crop, hunting, gathering herbs, gathering shea nuts, pito/alcohol brewing, owning grocery store etc.). Each livelihood was coded as a binary response (i.e., 1 = yes and 0 = no). These livelihoods were further categorized into 0 = no; 1 = farm; 2 = nonfarm; and 3 = both farm and nonfarm livelihood diversifications, following Ellis (1998), and Loison (2015).

For the analysis, theoretically relevant predictors of resilience to climate change from the sustainable livelihood and vulnerability literature were included. These variables include age (0 = less than 20, 1 = 20-24, 2 = 25-29, 3 = 30-34, 4 = 35-39, 5 = 40-44, 6 = 45-49, 6 = 50 and above); gender (0 = male, 1 = female); household size (0 = 1-4, 1 = 5-7, 2 = 8-11, 3 = 12 and above); education (0 = tertiary , 1 = no formal, 2 = primary, 3 = secondary); marital status (0 = married, 1 = single, 2 = widowed/divorced); religion (0 = Christian, 1 = Muslim, 2 = traditionalist); credit (0 = no access 1 = formal, 2 = informal); farm power (0 = tractor, 1 = animal, 2 = manual); family structure (0 = extended family, 1 = nuclear family, 2 = family without husband, 3 = family without wife); decision making (0 = only male household head, 1 = only female household head, 2 = joint household); cropping practice (1 = monocropping, 2 = multiple cropping); climate information (0 = personal, 1 = local community, 2 = external experts); and wealth (0 = richest, 1 = richer, 2 = middle, 3 = poorer, 4 = poorest). Household wealth categories were created from a composite index using the number of household assets such as vehicle, TV, tractor, fridge, mobile, hoe and radio.

4.4.3 Analysis

The survey data was analyzed in R-studio. Descriptive statistics were computed for all variables to understand the dependent and independent variables' distribution across the sample. A bivariate proportional odds logistic model was first computed between each covariate and the outcome variable (resilience), followed by a nested multivariate proportional odds logistic model controlling for individual, household and farm level factors. The nature of the outcome variable (poor, satisfactory and good) informed the regression model choice. We checked for multicollinearity in the regression model using Variable Inflation Factor (VIF). All VIF values for the variables were less than 2.0, which indicates that variables used in the multivariate regression model are not highly correlated. The results of the regression models are shown in odds ratios (OR). The equation for the ordered/proportional odds logistic regression model is given as;

$$log\,\frac{P(Yij\leq 1)}{(1-P(Yij\leq 1)} = a_0 + \sum_{k=1}^{p-1}\left(a_{jk}\,X_{ijk} + V_{ij,}C = 1, \ldots . \Omega - 1\right) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\mathbf{2}$$

Where $P(Yij \leq 1)$ indicates the probability that an event (e.g. a household reports good resilience as opposed to satisfactory or poor) will occur. The probability that the event will not occur is represented by (1 - $P(Yij \leq 1)$. Explanatory variables are *Xijk*, (k=1) is the first explanatory variable and (*p*—1) is the last explanatory variable. *Vij* is the error term in the logistic model, α_0 and Ω - 1 are the intercept terms, and α_{jk} *is the* coefficient term (Hedeker et al., 2000).

4.5 Results

Table 4.2 shows findings from the univariate analysis. About 47% of households rated their resilience to climate change as good, 27% rated their resilience to climate change as satisfactory and 26% rated their resilience to climate change as poor. Petty trade (about 44%) was the highest reported livelihood activity. Other major livelihood activities included owning businesses (28%), pito/alcohol brewing (21%), casual labour (20%), cash crops (19%), livestock trade and products (22%), and formal salary (14%). Generally, households were observed to be increasingly engaging in alternative livelihood adaptations aside from regular subsistence farming. More than half (75%) of households were engaged in only nonfarm diversification, 6% were engaged in only farm diversification, about 23% were engaged in both farm and nonfarm diversification. About 52% of participants were male and 48% were female (Table 4.2). More than two-thirds of participants had no formal education. The majority of participants were married (82%). The respondents were predominantly Christians (61%), with 22% and 17% being Traditional believers and Muslims, respectively. The mean farm size was 4.9 acres. More than half of the smallholder households ploughed their farms using tractors, while 20% ploughed manually and only 3% used animals. About 75% of the households reported that only the male household head made household decisions.

Table 4. 2: Descriptive statistics of smallholder livelihoods and climate resilience in semi-arid northern Ghana.

Variables		Percentages (%)	No. of Response
Climate Change Resilience	Poor	26	282
	Satisfactory	27	301
	Good	47	517
Livelihood diversification	None	1	15
	Only Farm	6	65
	Only Nonfarm	70	771
	Farm and Nonfarm	23	249
Age	< 20	1	11
	20-24	6	66
	25-29	8	86
	30-34	10	107
	35-39	16	180
	40-44	15	167
	45-49	18	198
	50 and above	26	285
Gender	Male	52	567
	Females	48	533
Marital Status	Married	82	908
	Single	12	128
	Divorced/widowed	6	64
Religion	Christian	61	676
	Muslim	17	186
	Traditional	22	238
Education	Tertiary	4	47
	No Formal	67	739
	Primary	17	184
	Secondary	12	130
Household Size	1-4	16	175
	5-7	45	496
	8-11	27	296
	Above 12	12	126
	Extended	27	296

Family Structure	Nuclear	70	762
	Family without husband	2	26
	Family without wife	1	15
Wealth	Richest	19	206
	Richer	17	190
	Middle	22	248
	Poorer	22	238
	Poorest	20	218
Source of Credit	No Credit	54	597
	Formal	36	390
	Informal	10	113
Decision Making	Only Male Household Head	75	830
	Only Female Household Head	9	93
	Joint Household	16	177
Climate Information	Personal Experience	21	232
	Local Community	62	683
	External Experts	17	185
Farm size		4.91 (mean)	Min = 0, Max = 30
Source of Farm Power	Tractors	77	852
	Animal	3	31
	Manual	20	217
Cropping Practice	Monocropping	47	511
	Multiple cropping	53	584

Source: 2019 FLAP Survey, Upper West Region, Ghana.

Evidence of climate change impacts from the perspective of farmers is important for discussion of livelihood diversifications. Table 4.3 summarizes the relationship between farmers' perceptions and experiences of climate change and livelihood diversification. Data from Table 4.3 indicates that almost all (99%) households that had experienced climate variability and change over the past 12 months preceding the survey diversified their livelihood outside primary

crop production. Interestingly, most diversifications were nonfarm. For example, farmers that experienced drought in the past 12 months preceding the survey diversified into farm (12.5%, $\chi^2 = p < 0.001$), nonfarm (49.12%, $\chi^2 = p < 0.001$) and both farm and nonfarm (38.16%, $\chi^2 = p < 0.001$) activities. Similarly, farmers that perceived climate change and variability to be a top priority relative to other socio-ecological challenges in Upper West diversified into farm (3.82%, $\chi^2 = p < 0.001$), nonfarm (84.73%, $\chi^2 = p < 0.001$) and both farm and nonfarm activities (11.07%, $\chi^2 = p < 0.001$). Table 4.3 clearly shows that smallholder farmers' perceptions and experience of climate change and variability form the basis for livelihood diversification in the Upper West, as growing literature also continue to demonstrate (Dapilah & Nielsen, 2019; Asravor, 2018).

Table 4. 3. Farmers' perceptions and experiences of climate variability and change and livelihood diversification (n=1100)

Climate Change Experience and Perceptions	**Livelihood diversification (%)**				χ^2
	None	Only Farm	Only nonfarm	Both farm and nonfarm	
Experienced severe drought in the last 12 months	0.22	12.50	49.12	38.16	***
Experienced severe flooding in the last 12 months	-	18.99	21.52	59.49	***
Experienced storm surge in the last 12 months	-	10.40	51.24	38.36	***
Experienced erratic rainfall in the last 12 months	-	4.69	79.30	16.01	**
Farmer rates climate variability and change as a top priority relative to other socio-ecological problems in the Upper West Region	0.38	3.82	84.73	11.07	***

Source: 2019 FLAP Survey, Upper West Region, Ghana; **p < 0.01, *** p < 0.001

Results from the bivariate analysis are shown in Table 4.4. The study revealed that households that diversified into only farm (OR = 7.30; $p \leq 0.001$) livelihood adaptations were 7 times more likely to rate their resilience to climate change as good compared to those who did not diversify into any livelihood activity. Similarly, households that diversified into both farm and nonfarm (OR = 9.92; $p \leq 0.001$) livelihoods were almost 10 times more likely to rate their resilience to climate change as good compared to households that did not diversify. Individual-level factors such as age, marital status, religion and education of the primary household farmer were significantly related to household resilience to climate change. For example, households where the primary farmer was single (OR = 1.88; $p \leq 0.001$) had higher odds of rating their resilience to climate change as good than households where the primary farmer was married. Households where the primary farmer practiced Traditional African Religion (OR = 4.45; $p \leq 0.001$) or Islam (OR = 1.62; $p \leq 0.001$) had higher odds of rating their resilience to climate change as good compared to households where the primary farmer practiced Christianity. At the household level, households with access to formal (OR = 2.13; $p \leq 0.001$) and informal (OR = 1.80; $p \leq 0.01$) sources of credit were more likely to report good resilience than households with no access to credit.

Table 4. 4: Bivariate ordered logistic regression of predictors of smallholder households' resilience to climate change

Covariates	**OR(SE)**	**CI**
Livelihood diversification (ref: None)		
Only Farm	7.30(0.602)***	2.244 - 23.768
Only Nonfarm	0.66(0.508)	0.243 - 1.776
Farm and Nonfarm	9.92(0.538)***	3.454 - 28.512
Age (ref: 18-25)		
20-24	2.35(0.655)	0.651 - 8.495
25-29	1.7(0.638)	0.486 - 5.935
30-34	1.82(0.630)	0.527 - 6.245
35-39	2.42(0.622)	0.717 - 8.197
40-44	2.45(0.623)	0.723 - 8.317
45-49	1.59(0.620)	0.473 - 5.371
50 and above	0.87(0.615)	0.262 - 2.920
Gender (ref: Male)		
Females	1.2(0.113)	0.965 - 1.502
Marital Status (ref: Married)		
Single	1.88(0.193)***	1.289 - 2.746
Divorced/widowed	0.58(0.235)*	0.367 - 0.922
Religion (ref: Christian)		
Muslim	1.62(0.153)***	1.202 - 2.190
Traditional	4.45(0.158)***	3.264 - 6.068
Education (ref: Tertiary)		
No Formal	1.14(0.309)	0.622 - 2.086
Primary	0.56(0.295)	0.315 - 1.003
Secondary	1.46(0.270)	0.859 - 2.474
Household Size (ref: 1-4)		
5-7	1.3(0.164)	0.941 - 1.791
8-11	1.87(0.179)***	1.317 - 2.659
Above 12	2.29(0.222)***	1.482 - 3.539
Family structure (ref: Extended)		
Nuclear	0.99(0.127)	0.772 - 1.272
Family without husband	0.61(0.365)	0.300 - 1.251
Family without wife	1.29(0.503)	0.481 - 3.461
Wealth (ref: Richest)		
Richer	1.07(0.187)	0.743 - 1.545
Middle	1.06(0.177)	0.752 - 1.506
Poorer	2.02(0.178)***	1.424 - 2.863
Poorest	6.7(0.206)***	4.473 - 10.036
Source of Credit (ref: No Credit)		
Formal	2.13(0.123)***	1.678 - 2.714
Informal	1.8(0.190)**	1.239 - 2.611
Decision Making (ref: Only Male Household Head)		
Only Female Household Head	0.87(0.201)	0.587 - 1.291
Joint Household	1.38(0.167)	0.991 - 1.907
Climate Information (Ref: Personal Experience)		
Local Community	2.93(0.151)***	2.180 - 3.948
External Experts	0.2(0.214)***	0.134 - 0.310
Farm size	0.99(0.011)	0.966 - 1.010
Source of Farm Power (ref: Tractors)		
Animal	0.91(0.356)	0.455 - 1.833
Manual	4.14(0.170)***	2.971 - 5.782

Cropping Practice (ref: Monocropping)		
Multiple cropping	0.52(0.114)***	0.419 - 0.656

* p<0.05, ** p<0.01, *** p<0.001 OR = Odds Ratio, SE = Standard Error, CI = Confident interval

Also, households with 8-11 (OR = 1.87; p≤0.001) and above 12 (OR = 2.29; p≤0.001) members were more likely to report good resilience than households with 1-4 members. Regarding farm level factors, households that used manual tools (OR = 2.99; p≤0.001) as a source of farm power were more likely to report good resilience than households that used tractors.

4.5.1 Multivariate analysis

Results of the multivariate regression analysis is shown in Table 4.5. We first controlled for individual level factors of the primary farmer and the result was mostly consistent with the bivariate analysis. The results showed that households that diversified into only farm (OR = 4.13; p≤0.05) and both farm and nonfarm (OR = 5.65; p≤0.001) livelihood adaptations were more likely to rate their resilience to climate change as good than households that did not diversify. This is reiterated in the marginal effect plots in Figure 4.2. After controlling for household level factors, households that diversified into both farm and nonfarm (OR = 3.17; p≤0.05) livelihood adaptations remained more likely to rate their resilience to climate change as good (as reinforced in Figure 4.3) compared to households that did not diversify their livelihood. However, only farm livelihood adaptations were not significant in model 2. Lastly, we controlled for farm level factors. Households that diversified into only farm (OR = 3.95; p≤0.05) livelihood adaptations were about 4 times more likely to rate their resilience to climate change as good compared to households that did not diversify. Also, households that diversified into both farm and nonfarm

(OR = 5.77; p≤0.01) livelihoods were about 6 times more likely to rate their resilience to climate change as good compared to households that did not diversify. Figure 4.4 shows the predicted marginal effects of livelihood diversification adjusting for all other independent variables. It shows that, households that diversified into both agricultural and non-agricultural activities have the highest probability of rating their resilience to climate change as good, followed by those who diversified into only agricultural livelihoods.

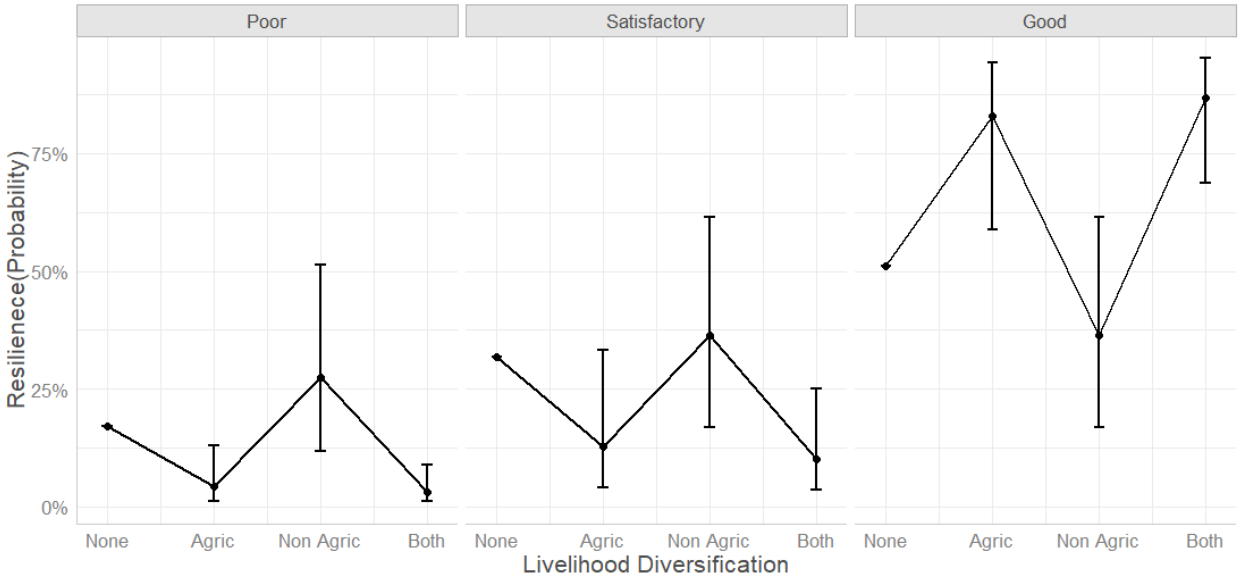

Figure 4. 2: Predicted probabilities of household resilience (95% confidence interval) adjusting for demographic factors (age, gender, marital status, and education).

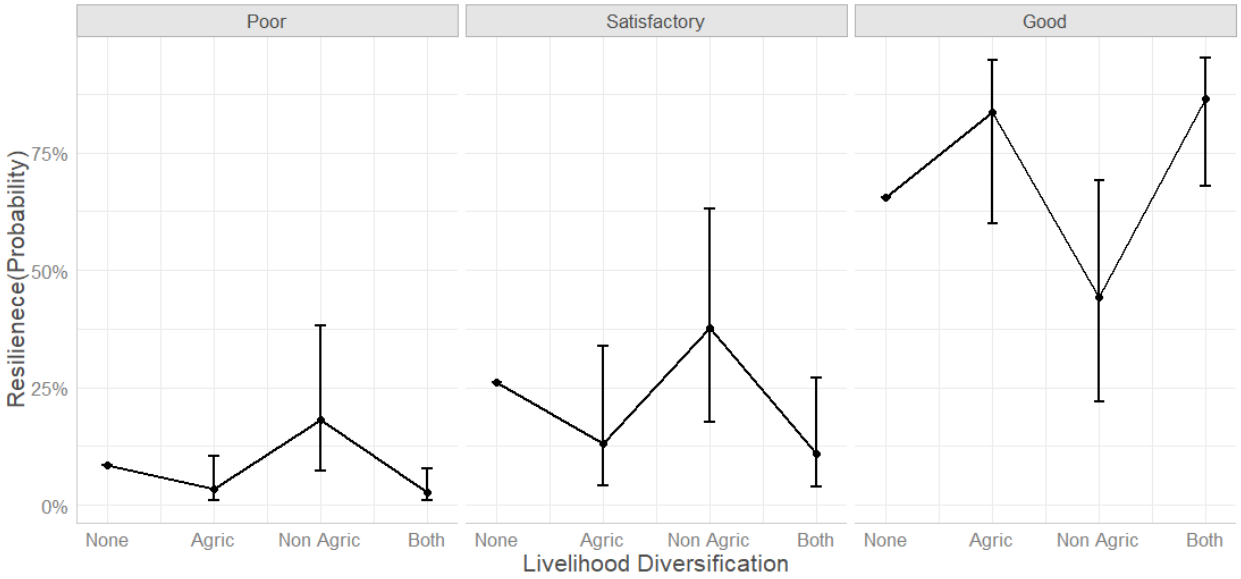

Figure 4. 3: Predicted probabilities of household resilience (95% confidence interval) adjusting for demographic factors (age, gender, marital status, and education) and household level factors (household size, household structure, wealth, credit source, climate information).

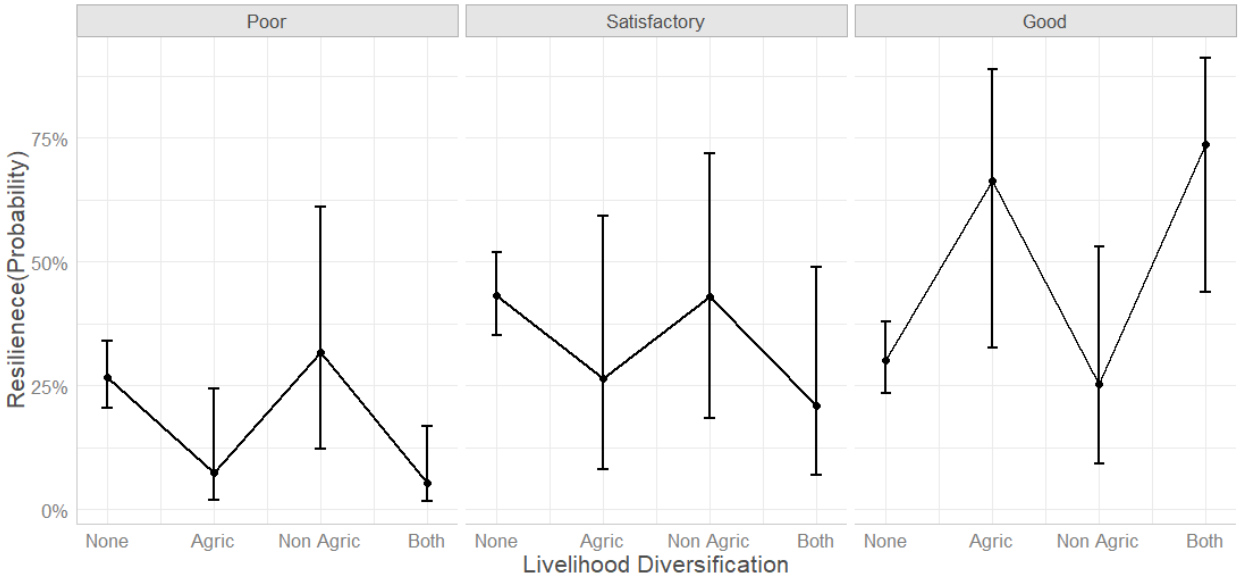

Figure 4. 4: Predicted probabilities of household resilience (95% confidence interval) adjusting for demographic factors (age, gender, marital status, and education), household level factors (household size, household structure, wealth, credit source, climate information) and farm-level factors (farm size, farm power, crop practice).

In the final model (as shown in Table 4.5), there were other significant predictors of smallholder household resilience worth mentioning. Households where the primary farmer practiced African Traditional Religion (OR = 1.76; $p \leq 0.01$), were more likely to rate their resilience as good compared to households where the primary farmer was a Christian. Results also indicated that education was significantly related to household resilience. Households where the primary farmer had attained only primary education (OR = 0.45; $p \leq 0.05$) had lower chances of rating their resilience as good compared to households where the primary farmer attained tertiary education. Smallholder households that used manual (OR = 4.48; $p \leq 0.001$) farm power were more likely to rate their resilience as good compared to households that used tractors. Also, households that received climate information from their local community (OR = 2.10; $p \leq 0.001$) were more likely to rate their resilience as good compared to households that relied on their personal experience. However, smallholder households that received climate information from external experts (OR = 0.27; $p \leq 0.001$) were less likely to rate their resilience as good.

Table 4. 5: Multivariate ordered logistic regression of predictors of smallholder households' resilience to climate change.

Covariates	**Model 1**		**Model 2**		**Model 3**	
	OR(SE)	**CI**	**OR(SE)**	**CI**	**OR(SE)**	**CI**
Livelihood diversification (ref: None)						
Only Farm	4.13(0.629)*	1.202 - 14.161	2.48(0.644)	0.701 - 8.765	3.95(0.686)*	1.028 - 15.141
Only Nonfarm	0.49(0.529)	0.172 - 1.367	0.41(0.541)	0.141 - 1.176	0.7(0.588)	0.221 - 2.217
Farm and Nonfarm	5.65(0.560)***	1.884 - 16.931	3.17(0.579)*	1.018 - 9.863	5.77(0.626)**	1.692 - 19.672
Age (ref: < 20)						
20-24	2.95(0.704)	0.743 - 11.722	2.23(0.768)	0.496 - 10.060	2.07(0.801)	0.431 - 9.955
25-29	2.49(0.699)	0.634 - 9.808	1.82(0.765)	0.406 - 8.159	1.82(0.801)	0.379 - 8.752
30-34	3.48(0.720)	0.848 - 14.250	2.39(0.793)	0.506 - 11.308	2.14(0.826)	0.423 - 10.786
35-39	3.01(0.713)	0.744 - 12.189	1.76(0.785)	0.378 - 8.201	1.76(0.818)	0.353 - 8.733
40-44	2.42(0.720)	0.590 - 9.917	1.67(0.790)	0.355 - 7.869	1.74(0.825)	0.347 - 8.780
45-49	1.93(0.714)	0.475 - 7.813	1.45(0.786)	0.311 - 6.758	1.41(0.821)	0.282 - 7.059
50 and above	1.12(0.713)	0.278 - 4.541	0.95(0.782)	0.204 - 4.385	1.03(0.818)	0.206 - 5.099
Gender (ref: Male)						
Females	1.25(0.133)	0.959 - 1.617	0.96(0.152)	0.716 - 1.298	1.01(0.156)	0.746 - 1.374
Marital Status (ref: Married)						
Single	2.62(0.270)***	1.546 - 4.449	2.37(0.289)**	1.346 - 4.172	1.93(0.297)*	1.079 - 3.456
Divorced/widowed	1.06(0.269)	0.628 - 1.800	0.92(0.341)	0.474 - 1.806	0.79(0.357)	0.392 - 1.587
Religion (ref: Christian)						
Muslim	1.08(0.172)	0.772 - 1.511	1.01(0.185)	0.704 - 1.455	1.28(0.191)	0.883 - 1.867
Traditional	2.39(0.186)***	1.660 - 3.443	1.68(0.202)*	1.130 - 2.495	1.76(0.208)**	1.173 - 2.648
Education (ref: Tertiary)						
No Formal	0.91(0.341)	0.469 - 1.782	0.78(0.370)	0.378 - 1.610	0.7(0.373)	0.335 - 1.444
Primary	0.49(0.318)*	0.263 - 0.915	0.55(0.348)	0.279 - 1.094	0.45(0.352)*	0.228 - 0.905
Secondary	0.99(0.304)	0.547 - 1.798	0.93(0.329)	0.490 - 1.781	0.78(0.333)	0.407 - 1.504
Household Size (ref: 1-4)						
5-7			0.8(0.202)	0.535 - 1.181	0.9(0.209)	0.600 - 1.359
8-11			0.75(0.241)	0.471 - 1.210	0.98(0.251)	0.599 - 1.603
Above 12			0.71(0.319)	0.382 - 1.336	1.05(0.339)	0.542 - 2.043
Family structure (ref: Extended)						
Nuclear			1.19(0.179)	0.839 - 1.692	1.31(0.184)	0.909 - 1.873
Family without husband			1.12(0.481)	0.436 - 2.873	1.11(0.500)	0.418 - 2.966
Family without wife			0.68(0.679)	0.180 - 2.576	0.67(0.715)	0.166 - 2.737

Wealth (ref: Richest)					
Richer		1.03(0.217)	0.673 - 1.573	1.12(0.222)	0.728 - 1.739
Middle		0.98(0.207)	0.653 - 1.469	0.96(0.213)	0.631 - 1.455
Poorer		1.64(0.215)*	1.073 - 2.497	1.61(0.222)*	1.039 - 2.484
Poorest		3.11(0.255)***	1.888 - 5.137	3.12(0.269)***	1.843 - 5.281
Source of Credit (ref: No Credit)					
Formal		0.69(0.172)*	0.496 - 0.974	1.03(0.183)	0.719 - 1.474
Informal		1.00(0.231)	0.633 - 1.567	1.36(0.240)	0.849 - 2.176
Decision Making (ref: Only Male Household Head)					
Only Female Household Head		1.37(0.287)	0.780 - 2.406	1.08(0.297)	0.604 - 1.936
Joint Household		1.29(0.209)	0.858 - 1.944	1.12(0.216)	0.732 - 1.707
Climate Information (Ref: Personal Experience)					
Local Community		1.91(0.189)***	1.319 - 2.767	2.1(0.201)***	1.419 - 3.121
External Experts		0.24(0.235)***	0.150 - 0.377	0.27(0.241)***	0.169 - 0.435
Farm size				0.94(0.036)	0.876 - 1.010
Source of Farm Power (ref: Tractors)					
Animal				0.87(0.466)	0.349 - 2.172
Manual				4.48(0.218)***	2.919 - 6.867
Cropping Practice (ref: Monocropping)					
Multiple cropping				1.42(0.166)*	1.021 - 1.961
Pseudo R2	0.3506704	0.4536371		0.504577	
Akaike Information Criteria (AIC)	1962.855	1842.992		1767.873	
Log likelihood	-961.4276	-885.4962		-843.9365	

* p<0.05, ** p<0.01, *** p<0.001 OR = Odds Ratio, SE = Standard Error, CI = Confident interval

4.6 Discussions

The study explored the relationship between smallholder livelihood diversification strategies and climate change resilience. Our study particularly contributes to the empirical knowledge gap in the role of farm and nonfarm livelihood diversification strategies in resilience to climate change in smallholder communities. Notwithstanding the link between livelihood diversification and climate adaptation and resilience in agrarian communities, the role livelihood diversification strategies play in climate adaptation and resilience has not been fully explored (Haggblade et al., 2010). Livelihood diversification has been viewed to be beneficial when diversification is completely outside agriculture. Studies have demonstrated that nonfarm livelihood diversification is a beneficial risk diversification strategy (see Dapilah et al., 2020; Barrett et al., 2001; Haggblade et al., 2007; Tsiboe et al., 2016). We offer an alternate empirical narrative to understanding the risk-spreading role of livelihood diversification. We demonstrate that farm and nonfarm livelihoods are concurrent and complementary livelihood strategies that may facilitate inflow of resources between the two livelihood adaptations, especially in resource-constrained settings like semi-arid Ghana. Farm and nonfarm livelihoods are not mutually exclusive, thus exploring the synergies between farm and nonfarm livelihoods may prove beneficial in agrarian context. More so, this study offers a nuanced understanding of the role of farm livelihood diversification in climate change resilience. Our findings suggest that households diversifying into both farm and nonfarm livelihoods have higher odds of good resilience to climate change in the context of smallholder communities.

The positive role farm livelihood diversification play in smallholder farmers' resilience to climate change may be explained by the longstanding reliance of rural livelihoods on the agrarian economy in semi-arid Ghana. Smallholder livelihoods are primarily dependent on the production and trade of agricultural goods and other ecosystem services, for which reason, farm diversification

strategies can help ensure risk spreading. Growing demand for high-value food such as fruits, vegetables, meat, fish and eggs in both urban and peri-urban areas presents opportunities for smallholder farmers to diversify into alternative farm-based livelihoods such as fishing, livestock rearing and vegetable gardening for additional income (Joshi et al., 2007; Barghouti et al., 2004). Notwithstanding the importance of nonfarm livelihoods, the relatively capital-intensive requirement of nonfarm livelihoods (Barrett et al., 2001; Reardon, 1997) may render them less beneficial in poverty-stricken rural settings like semi-arid northern Ghana. Amid scarce capital in smallholder rural communities and the urgent need for adaptation, diversification into farm activities may offer more prospects for livelihood security in agrarian rural communities. The study further revealed that households that diversified into both farm and nonfarm livelihoods had the best chance of being resilient to climate change stresses, reinforcing the idea of complementarity, rather than competitive nature of farm and nonfarm livelihoods. Our findings concur with Babatunde (2013) and Pfeiffer et al. (2009), who demonstrate that the impact of nonfarm livelihoods on household livelihood security depends on whether it complements farm livelihoods or substitutes it. Concurrent diversification into farm and nonfarm livelihoods facilitate the inflow of resources between the two livelihood adaptations. Amid inaccessible capital from financial institutions in smallholder communities in Ghana (Abdallah, 2016; Twumasi et al., 2019), the intensive capital requirements of nonfarm livelihoods could in part, be satisfied by the inflow of capital from farm livelihood activities. Symbiotically, nonfarm livelihoods can provide capital for farmers to invest in short-term coping (e.g. purchase of fertilizer, seed, pesticide) or long-term (e.g. investment in irrigation, improved crop varieties) adaptation strategies (Pfeiffer et al., 2009). However, in rural communities where livelihood and economic activities are heavily dependent on agriculture, nonfarm diversification could adversely impact livelihood and economic growth if households decide to abruptly migrate outside agriculture entirely (Pfeiffer et al., 2009). Thus, in smallholder farming

communities, synchronized diversification into farm and nonfarm diversification may enhance synergies to facilitate climate change adaptation and resilience.

The study also revealed that households that used manual tools such as hoes and cutlass for ploughing their farms had higher chances of reporting good resilience to climate change compared to households that used tractors. This finding reinforces the mechanization paradox in Ghana highlighted by Kansanga et al. (2019), which suggests that traditional agriculture, which is characterized by the use of manual tools such as hoes and cutlass promotes the cultivation of a wide range of traditional crops compared to tractor use which has been confined to maize monoculture. The use of tractors may further disrupt women's alternative livelihoods, such as gathering shea nuts as tractor use facilitates the widespread removal of major trees, including trees with livelihood significance in the northern savannah (Kansanga et al., 2019; Yaro, 2013). Therefore, using tractors may impede household capacity to adapt by limiting the range of crops cultivated and increasing the depletion of vital alternative livelihood activities like shea processing. Similarly, the study found that the poorer and poorest household were surprisenly more likely to have good resilience to climate change compared to the richest. This maybe explained by the fact that, in smallholder communities, wealth is not the only mediator of resilience to climate change. Other factors such as indigenous knowledge systems and farm practices influence farmers response to climate change and other environmental stressors (Ajani et al., 2013). Impoverished smallholder households who are engaged in agroecological practices with indigenous farming tools and knowledge maybe better adapted to environmental stressors (Kansanga et al., 2019).

Also, single people were more likely to be resilient to climate change than married people. This finding may be explained by the differences in dependency burden between single individuals and married couples. In northern Ghana, the household heads are usually the sole breadwinners of the family (Nyantakyi-Frimpong et al., 2019). Thus, given the same resources, umarried people (i.e., without

dependents) may have more resources available for effective adaptation strategies compared to married people with dependents.

The findings further show that religion was a significant predictor of resilience. This is consistent with Golo and Yaro (2013), and Nyantakyi-Frimpong (2020), who argue that climate change policy has been far driven by 'technological fixes' with the neglect of religious and traditional indigenous knowledge and practices. However, the views of devout religious leaders significantly affect climate change adaptation strategies. It is no doubt that Traditional African religion practitioners were found to be more likely to report good resilience compared to Christians. Traditional African religion is the foundation of all forms of social metabolism in Africa, including agriculture (Granderson, 2017). Since prehistoric times, smallholder agriculture has been founded on traditional knowledge systems, passed down from generation to generation. Indeed, empirical research shows that traditional knowledge systems are well adapted to the local environment and are relatively effective in addressing climate change (Savaresi, 2018; Granderson, 2017; Janif et al., 2016). Smallholder farmers who hold these traditional beliefs may, therefore, be better adapted to environmental changes. Traditional agricultural societies also have beneficial social norms like labor sharing, which can promote climate change adaptation (Adimassu & Kessler, 2016). For instance, communal labor sharing practices enable smallholder farmers to plant timely to avoid crop failure. Traditional African believers also had more household farm labor, which may be attributed to their practice of polygamy. High household farm labor may translate to an increase in 'Total Factor Productivity'.

Related to the role of traditional knowledge in climate change adaptation, we found that households that relied on climate information from local communities had higher chances to be resilient to climate change. The role of local climate information in smallholder households' resilience to climate change could be explained by the importance of indigenous traditional knowledge and practices in

coping with environmental change and shocks. Smallholder farmers in SSA have coevolved with environmental changes for decades and have devised coping strategies to environmental shocks including the prediction of weather variability (Ajani et al., 2013; Nyantakyi-Frimpong, 2013; Guthiga & Newsham, 2011). A study conducted in Kenya showed that indigenous traditional 'rainmakers' used observation of flora and fauna in weather prediction and had strikingly similar outcomes to expert meteorological predictions (Guthiga & Newsham, 2011). The negative association between external expert climate information and climate resilience may be explained by the inadequacy of weather stations in rural areas in Ghana, thereby hindering location-specific weather predictions by regional meteorological services. In the absence of adequate and accurate meteorological data, indigenous weather prediction may prove more useful.

Multiple cropping was observed to be significantly related to smallholder farmer household resilience to climate change. Amid climate change, multiple cropping may help guard against crop failure. Our finding is consistent with literature indications (Beets, 2019; Mukadasi, 2018; Waha et al., 2013) that multiple cropping allows for crop intensification while mitigating pest/disease infestation in crops. Multiple cropping also improves soil nutrients, for example, the symbiotic relation between leguminous plants and the rhizobium bacteria fix nitrogen in the soil which is utilized by plants (Palm & Sanchez, 1990). Multiple cropping is a risk diversification strategy hence, considering the rapid environmental stress on agriculture, multiple cropping could serve as harvest security for smallholder farming households.

While these findings provide useful insights on livelihood diversification as a potential tool for addressing climate change, some limitations are worth highlighting. Given that resilience is a self-reported measure in our survey, there is a likelihood of potential response bias. As a household level survey, the study was unable to capture the variation in intra-household level perceived resilience and

perceptions of primary household farmers may not be representative of individual perceived resilience to climate change. Since the primary household farmer reported on behalf of all other household members, some livelihood activities of household members may be unknown to the primary farmer at the time of the survey. This may lead to overestimation or underestimation of household livelihood activities. The income from livelihood activities is essential for smallholder farmers' climate adaptation to environmental stress (Atuoye et al., 2019; Barrett et al., 2001). However, due to lack of reliable income data in smallholder communities such as our study area, the income differences from various livelihood activities were not captured. The findings are also based on cross-sectional data limiting our findings to statistical associations. There is a need for longitudinal analysis to examine the causal relationship between livelihood diversification and climate change resilience. Qualitative analysis may also present a more revealing causal and insightful understanding of the contextual dynamics in the role of farm and nonfarm livelihoods in smallholder household resilience to climate change.

4.7 Conclusions

Overall, this study demonstrates that livelihood diversification is positively associated with resilience to climate change in smallholder farming communities. These findings suggest that agricultural and development policies must be broadened to include critical issues such as livelihood diversification. In semi-arid Ghana, and similarly impoverished agrarian settings across SSA, synchronized diversification into both farm and nonfarm livelihood activities may prove more beneficial and sustainable than an abrupt total diversification outside agriculture (nonfarm). Amid the increasing climatic changes and variability, the need to promote alternative local livelihood diversification systems is warranted. Therefore, policies targeted at improving smallholder agriculture must be pursued alongside community enterprise development and skillset development to help smallholder farmers diversify production into

farm and nonfarm activities as complementary livelihoods. This way, the risk-spreading potential of livelihood diversification can be leveraged to address underlying poverty and food insecurity in semi-arid Ghana and similar contexts in the Global South. This policy direction must also consider relevant underlying factors such as indigenous knowledge, climate information sharing systems, and farm management practices such as multiple cropping to maximize benefit to all stakeholders at the local level.

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Chapter 5

Intra-Household Decision-Making Arrangements and Food Security in Semi-arid Ghana

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5: Intra-Household Decision-Making Arrangements and Food Security in Semi-arid Ghana

Household decision making is crucial in navigating household food insecurity amid increasing climate change and variability. In smallholder farming contexts in Ghana and other parts of Sub-Saharan Africa (SSA), decision making is often the culturally ascribed role of the male family head. Yet joint household decision making has the potential to leverage the diverse knowledge and capacities of household members to meet the nutritional and dietary needs of households. Using a cross-sectional survey involving 1100 smallholder farmer households, we examined the association between intra-household decision-making arrangements and food security in northern Ghana. Results from the logistic regression analysis indicated that households that practiced joint decision-making (OR = 1.71; $p \leq 0.001$) had significantly higher odds of being food secure compared to households that practiced sole decision-making. Other noteworthy socio-economic and agricultural practices that were significantly associated with household food security included household size, marriage type, wealth and Post-Harvest Loss. The findings have demonstrated that household decision-making arrangements influence how household members negotiate and reconcile preferences in the allocation of resources and consequentially household food security outcomes. Therefore, policies that seek to address food insecurity and other socio-economic challenges in such contexts must critically consider household decision-making arrangements. Gender transformative policy approaches that are inclusive of both women and men in a comprehensive dialogue on collective cooperation in household decision making and control of productive resources should be employed.

5.1 Introduction

Food is a fundamental human right, yet about 675 million people in Africa are food insecure (FAO et al., 2020). Food security exists "when all people, at all times, have physical, social and economic access to sufficient, safe and nutritious food" (FAO, 2009: 1). Food security is, therefore, not limited to the availability of food, but the accessibility and utilization of food sustainably (FAO et al., 2018). Food insecurity may exist when any one or more of the elements of food security (availability, accessibility, utilization, and sustainability) is/are compromised (FAO et al., 2018; Yaro, 2013). Hunger and malnutrition are particularly pressing issues in Sub-Sharan Africa (SSA), where underlying climate stress, conflict, and economic crises exacerbate food insecurity (FAO et al., 2020).

In the Ghanaian context, the prevalence of food insecurity varies geographically. The average food insecurity prevalence in southern Ghana is about 7%, however, food insecurity prevalence in northern Ghana range between 10% to 30% (Nyantakyi-Frimpong, 2013; Biederlack & Rivers, 2009). The longstanding food insecurity in northern Ghana could be primarily attributed to both socio-economic and climatic factors. Climate change stressors such as drought, flood and erratic rainfall thwart rain-fed agricultural systems and food production in northern Ghana (Nyantakyi-Frimpong, 2021). Socio-economic factors such as poverty, low levels of education, poor access to markets, and unstable food prices further exacerbate food insecurity in northern Ghana (Kuuire et al., 2013; Yaro, 2013c). Though the economic and climatic determinants of food security in smallholder context are acknowledged in literature, social factors such as decision making influence household food security outcomes (Stevano et al., 2020; Amugsi et al., 2016).

Agricultural decision making is crucial in navigating household food insecurity in smallholder communities, especially in the context of increasing climate change and variability. Here, agricultural decision making refers to consensus and participation in such issues as what to plant, where, when, and

how (Barlett, 2016). The role of decision making in proactive resource management at national, community and household levels is well acknowledged in empirical research (Wang et al., 2018; Fantahun et al., 2007). Also, household decisions on livelihood and adaptation strategies substantially contribute to household capabilities to anticipate, prepare, and recover from environmental and socio-economic shocks (Kerr et al., 2018). Studies have explored how household decision making informs the organization of household labor and resources in SSA (Zakaria, 2017; Amugsi et al., 2016; Kalinda et al., 2000). In smallholder communities, intra-household decision-making informs the utilization and allocation of scarce household resources (labor, capital and land) for production (Kalinda et al., 2000). In northern Ghana, deep-seated gender norms and patriarchal values continue to determine family authority structure and inherent household decision making (Nyantakyi-Frimpong, 2019). Males are often the de facto household heads and decision-makers. Gender inequality in participatory agricultural labor decisions hinders women's economic empowerment in northern Ghana (Zakaria, 2017). Despite growing literature on household decision making and gender relations in agriculture (Nyantakyi-Frimpong, 2021; Zakaria, 2017; Amugsi et al., 2016), the relationship between household decision-making arrangements and food security remain less understood, especially in patriarchal smallholder context.

This paper contributes to literature in two main ways. Firstly, it deepens understanding of the social aspects of food insecurity. Given the ongoing climate crisis, discussions around food insecurity tend to focus heavily on biophysical constraints to food production, including precipitation, soils, and temperature. The social mechanisms (e.g., decision making and gender relations) that shape how food is produced, accessed and utilized are often given a short shrift in contemporary discussions around food insecurity. Here, we show how intra-household decision-making arrangements continue to be a crucial underlying social driver of food insecurity in sub-Saharan Africa. Additionally, household decision making, and how it shapes food security, is often explored using qualitative case studies. Due to the

small samples of such studies, generalization is difficult, making it hard to use such results to inform food policy. Here, we offer an analysis based on a large-scale, representative survey. We hypothesize that households that practice joint decision-making are more likely to be food secure compared to those with a sole decision-making system.

5.2 Theoretical framework

Household bargaining theories are used to understand how the household as a unit engage in decision making and resource allocations. Intra-household bargaining describes the various mechanism of intra-household decision-making and power relations in resource allocations (Fiala & He, 2017; Doss, 2013). Bargaining models also emphasize how different socio-economic and cultural factors (e.g., gender, age) mediate power in the household. Unitary and Non-Unitary (collective and cooperative) bargaining are two broad categories of household bargaining that explain the processes of decision making and resource allocation in a household. Classical unitary household bargaining conceptualizes the household as a single decision making unit (Agarwal, 1997). With unitary household bargaining, household decision making and resource allocation are carried out by a sole decision maker in the household. This is based on the assumption that household members have aggregated interests and preferences (Manser & Brown, 1980). Unitary household bargaining is highly critiqued for its myopic view of the complexity of the household and the differences in intra-household preferences. The fundamental premise of unitary household bargaining is that all household resources are pooled together and distributed by a single household head in the interest of all household members (Haddad et al., 1997). However, this is unrealistic, as individual members of a household cannot at all times have the same or aggregated preferences (Lundberg & Pollak, 2016). Unitary household bargaining also reflects patriarchy in SSA, where decision making is the sole role of the male household head. Subsequent discussions on household bargaining have recognized that a household is rarely a unanimous unit because it constitutes

individual members with varying interests (Fiala & He, 2017; Doss, 2013). These models include collective and cooperative bargaining, broadly referred to as non-unitary household bargaining.

Alternatives to unitary household bargaining is non-unitary household bargaining which includes collective cooperative and non-cooperative intra-household bargaining frameworks. Non-unitary household bargaining allow for at least two primary decision makers (i.e., husband and wife). In agrarian context, children are customarily excluded from the decision-making process. However, the interactions between adult children and parents are critically considered in non-unitary cooperative bargaining (Lundberg & Pollak, 2016). Cooperative household bargaining is based on game theoretical models of household resource allocations, where the bargaining power of each household member is a function of available external options (fallback position and social legitimacy) (Agarwal, 1997). The bargaining power of household members can be changed by modifying these external options (Haddad et al., 1997). For example, in patriarchal societies, women's bargaining power could be increased by modifying an external factor such as their wages (Arthur-Holmes & Busia, 2020; Doss, 2013). The primary premise of cooperative household bargaining is that households can strive to attain 'Pareto efficiency' (Agarwal, 1997). In this regard, no individual member of the household can maximize their benefit without making another member worst off (Doss, 2013). Thus, Cooperative models postulate possible optimal outcomes that should be considered by households based on specified criteria (Seiz, 1995). Therefore, household members ought to negotiate and reconcile their different preferences. Cooperation exists when all household parties seek to benefit from cooperative arrangements as relative to non-cooperative arrangements (Fiala & He, 2017; Sen, 1987). Household members may disproportionately benefit from cooperation as cooperative arrangements are usually more favorable to household members with higher bargaining power (Agarwal & Bina, 1994). Contrary to cooperative household bargaining, noncooperative household bargaining do not assume that households attain Pareto efficiency. The

underlying assumption of non-cooperative household bargaining is that members are not able to reach an enforceable agreement on the production, distribution and consumption of household resources (Fiala & He, 2017; Agarwal, 1997). The separate spheres of non-cooperative models emphasize that households can achieve a non-cooperative equilibrium, which reflects the traditional gender norms, roles and expectations (Agarwal, 1997). Agarwal, (1997) argues that, though separate sphere models do not assume pareto efficiency, the outcome of such bargaining may be an equilibrium. In both cooperative and non-cooperative decision-making, the bargaining power of household members are vital in decision making and resource allocations.

The bargaining power of a household member is a function of the fallback position and the social, cultural and legal legitimacy of claim in the negotiation process (Agarwal & Bina, 1994). A household member's fallback position is an external alternative that determines how well-to-do they would be in a non-cooperative household scenario (Agarwal & Bina, 1994). A combination of a strong fallback position and a legitimate claim produces the most favorable outcomes in a household negotiation, particularly in cooperative bargaining. However, Sen (1987) emphasized that the outcome of household negotiations also depends on perceived interest response and perceived contribution response. Perceived interest response is the value placed on others' well-being relative to one's well-being and perceived contribution response is what is thought to be an individual's contribution to the household economy (Agarwal & Bina, 1994; Sen, 1987). Structural gender norms and roles mediate both perceived interest and contribution, especially in smallholder context. Women are often on the unfavorable side of both perceived interest and contribution (Haddad et al., 1997; Agarwal & Bina, 1994). Also, because women tend to prioritize the welfare of other household members relative to their well-being, they rarely have opposing preferences in household decision making (Agarwal & Bina, 1994). In traditional and patriarchal societies, women have less bargaining power in household decisions

due to structural norms that make household decision making the preserve of the male heads (Kansanga et al., 2019; Carney, 2004). Socio-cultural and economic intersecting factors such as age, wealth as well as household characteristic (e.g., family type, structure of household) may also create differences in the bargaining power among women, who generally have low bargaining power compared to men (Nyantakyi-Frimpong, 2019). While these norms are fast evolving in contemporary times, this study explores the association between household decision-making arrangement and food security.

The complexity of the household as a social unit is acknowledged in literature. The household is a sophisticated unit of relationships characterized by negotiation, cooperation and underlying mediating factors such as gender norms and traditions (McCarthy & Kilic, 2017; Agarwal & Bina, 1994). In smallholder rural context, the household is a composition of implicit and explicit negotiations and not merely a composition of the household members into a harmonious unit (Guyer, 1981). The composition of household and the activities they engage in are deeply influenced by the cultural and institutional contexts (Guyer, 1981). Guyer (1981) argues that when the focus of an analytic methodology is the household, three critical interactions should be considered: the age hierarchy among men, gender relationships and wealth disparities within the household. In rural smallholder communities, most households are a composition of an extended family that constitutes multiple adults. That notwithstanding, theoretical facets of bargaining models mostly assume and include two decision makers (Lundberg & Pollak, 2016). Aside this, most bargaining models implicitly assume that the two decision makers in question are a couple (Agarwal, 1997). Thus, a high number of bargaining models implicitly assume that, in a multi-member household, bargaining and decision making is between the husband and wife, and sometimes other adult household members (Lundberg & Pollak, 2016). Given that our study area comprises polygamous and extended families. We acknowledge that, joint decision-making may comprise adult household members (i.e., in extended families/nuclear families, and

monogamous/polygamous marriages with adult children) or the husband and wife (i.e., in monogamous and nuclear families without adult children). Families may make decisions either separately or jointly commensurate with the bargaining power of each member. Thus, joint decision-making may not necessarily be synonymous with equality in decision making because some members of the family might have more inputs in the decision-making process.

5.3 Study setting

Ghana is a sub-Saharan country located in West Africa with sixteen administrative regions. Accra, in the Greater Accra region is the capital of Ghana. Ghana has a total population of about 30 million people and a total land size of about 238,535 km². Northern Ghana comprises 5 administrative regions, namely: Northern Region, Savannah Region, Upper East Region, Upper West Region and North East Region. Northern Ghana has two main ecological zones, the Guinea and Sudan savannah ecological zones. The Guinea Savannah ecological zone covers the Upper West and Northern Regions and has an annual precipitation of about 1000 mm (Ghana Statistical Service, 2013). The Sudan Savannah ecological zone covers the north-eastern most part of the Upper East region, annual precipitations range between 500 mm to 700 mm (Ghana Statistical Service, 2013). Both the Guinea and Sudan Savannah ecological zones have unimodal precipitation patterns, limiting rain-dependent agricultural production to once a year.

This paper uses the Upper West Region as a case study. The region is located in the north-western part of Ghana around latitudes 9º 48' to 11º North and longitudes 1º 36' to 3º West (Figure 5.1). Upper West is bounded to the north and west by Burkina Faso, to the south by Savannah Region and the east by Upper East and North East Regions. The region has 11 administrative districts with Wa Municipal as the capital. According to the Ghana Statistical Service (2019), Upper West has a total population of about 702,110 people and covers an area of approximately 18,476 km², which represents

about 12.7% of Ghana's total land size. Agriculture is the main economic activity in the region, with about 80% of the population engaged in diverse activities in the agricultural production value chain (Ghana Statistical Service, 2013). The Upper West region is characterized by harsh climate conditions that thwart agricultural production and other livelihood activities. Upper West Region has the highest poverty incidence in Ghana, with over 70% of the population living on less than a dollar a day (Ghana Statistical Service, 2015). Also, the region has one of the highest food insecurity rates in Ghana with about 16% of the population is food insecure (WFP & MofA, 2012), which may be an underestimate. For example, Atuoye et al. (2019) found that over 60% of the households in the Upper West region are food insecure. Structural inequalities resulting from colonial and post-colonial policies neglect have also contributed to the high poverty rates and food insecurity in the northern regions (Yaro, 2013b; Songsore, 1983). Colonial policies depleted labor in the northern regions and neglected investment into potential resources (Yaro, 2013b). The region has a single cultivation season per annum due to the single maxima rainfall pattern from June to September (Dapilah & Nielsen, 2019).

Upper West region has an average minimum and maximum precipitation of about 840 mm and 14000 mm, respectively (Ghana Statistical Service, 2013). Annual rainfall in the Upper West has become irregular (Adiku et al., 2017), presenting challenges for timely cultivation. Average temperatures in the region are about 28°C, reaching a maximum of about 38° C. In the last decades, temperatures in the Upper West region have increased by 1.7° C and climate models project an increase of about 3° C by 2050 (Adiku et al., 2017). In the past few decades, climate stressors (e.g., erratic rainfall, drought, floods etc.), inadequate capital and inappropriate agricultural techniques have largely contributed to decrease in crop yields in the Upper West Region (Atuoye et al., 2019; Kansanga, Andersen, et al., 2019; Kansanga, Mkandawire, et al., 2019; Kuuire et al., 2013; Luginaah et al., 2009). Food insecurity and climate change are significant challenges in the region, consequentially, households

are increasingly engaging in livelihood diversification and migration as coping strategies (Mohammed et al., 2021; Atuoye et al., 2019; Kuuire et al., 2013). This post-colonial north-south migration also reflects the colonial labor recruitment initiatives and also indicates the high impoverishments in the north (Yaro, 2013b).

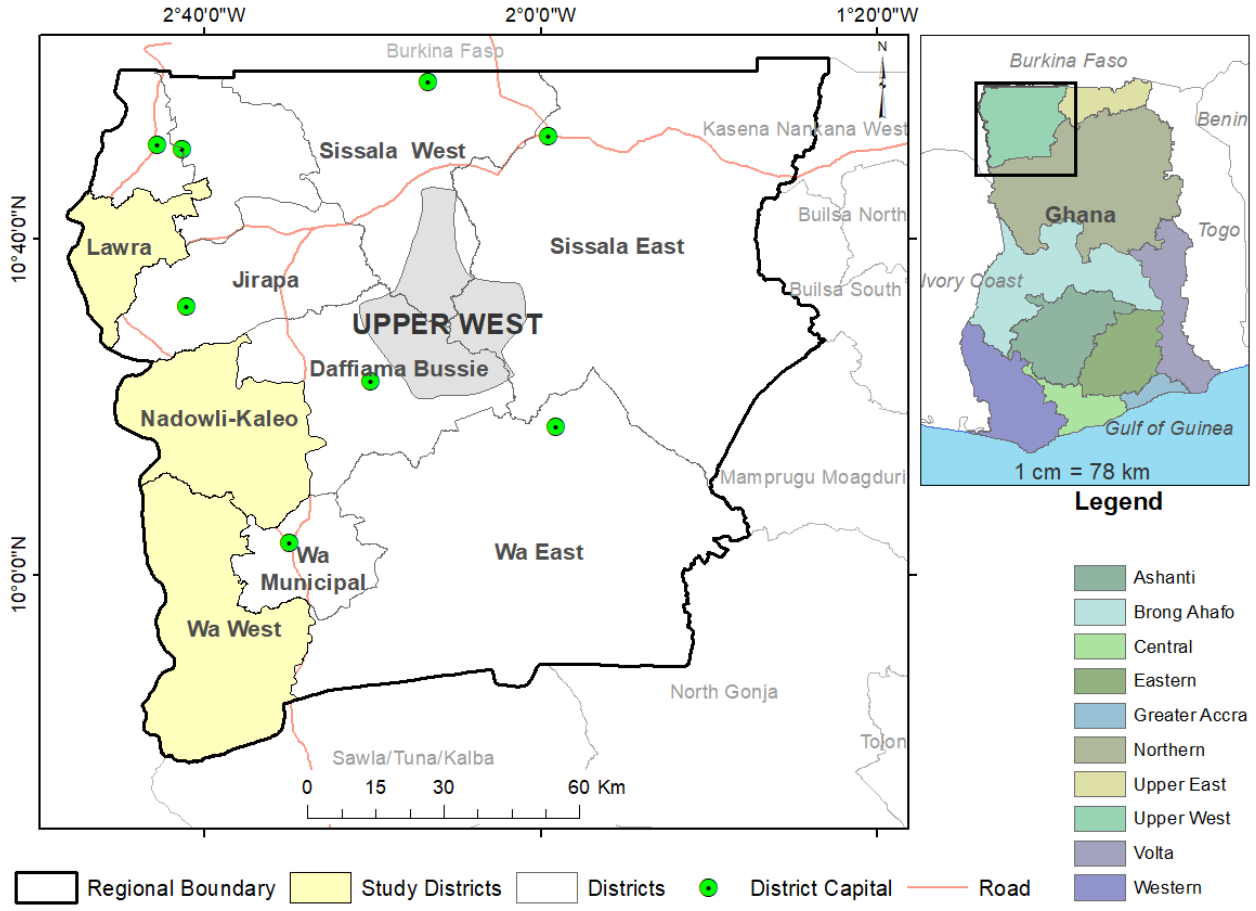

Figure 5. 1: Study Area Map of Upper West Region

Household and agricultural decision making in Upper West region are gendered. For example, regarding agricultural labour, men typically clear land while women plant seeds and process farm outputs after harvest (Nyantakyi-Frimpong, 2021). Aside from this gendered agricultural division of labour, women are primarily responsible for various household chores and activities such as caring for

children and the elderly in the household. Women also play critical roles in the nutritional and dietary requirements of the household members. Access to productive resources such as land and labour outrightly favours men through structural socio-cultural norms. For example, under the patrilineal land tenure systems, men are the custodians of lands through inheritance, women may only obtain user rights through male relatives such as husband, brothers, sons (Kansanga et al., 2019). Thus, even female-household heads may be restricted to marginalized lands obtained from male relatives (Nyantakyi-Frimpong & Bezner Kerr, 2017). More recently, gender roles and responsibilities have been evolving in northern Ghana to incorporate women into key domestic and other decision making roles (Vercillo et al., 2020; Kansanga, Mkandawire, et al., 2019). These are largely through Non-Governmental Organizations (NGOs) projects in partnership with the government. Despite some progress, structural gender inequalities persist, particularly in rural smallholder farming communities.

5.4 Methods

5.4.1 Data collection

This paper used data from a cross-sectional survey administered in the Upper West Region from July to August 2019. The survey team constituted 3 researchers and 6 local research assistants. The 3 researchers trained and supervised the 6 local research assistants to administer the survey in local languages. The research assistants approached eligible participants (primary farmers aged 18 or older) to administer the survey in the local languages. The research team first consulted community leaders (i.e., Chiefs) to inform them about the purpose of the study and introduce them to the research team. Potential participants were made aware that the study was strictly voluntary, with the assurance of confidentiality and anonymity. The survey team sought oral consent from participants in their local languages. Only participants who consented to participate in the study were asked further questions. A multistage sampling method was used to select 1100 participating smallholder farmer households. First, three

districts (Wa West, Lawra, and Nadowli-Kaleo) were selected using purposive sampling. These districts were purposively selected because a high proportion of their populations are highly impoverished smallholder farmers. For example, the Wa West district ranks number one as the poorest district in Ghana, while Lawra and Nadoeli-Kaleo rank 13th and 17th poorest districts (Ghana Statistical Service, 2019). Therefore, amid increasing climate stressors and high impoverishment, smallholder farmers in these districts are particularly vulnerable to food insecurity. Next, the participating smallholder communities in each district were selected using a simple random sampling technique. Finally, a systematic sampling technique was used to select household units by selecting every fifth house where the research team first enters the community/village. The primary farmer in each household responded to the survey on behalf of the household. Table 5.4 in the appendix details the topics/themes that were surveyed and the number of items in each topic/theme. Ethical approval was granted by the Non-Medical Research Board of the University of Western Ontario.

5.4.2 Measures

The outcome variable for this study is food security. Food security is a four-level ordered variable computed from 9 questions using the Household Food Insecurity Access Scale (HFIAS). HFIAS is a standardized measure of a household's perceptions of their food security status (Coates et al., 2007). The HFIAS assesses the prevalence of household food insecurity using a set of questions that explore key areas including the uncertainty or concern over food availability in the household; perceptions of food deficiency in quantity and/or quality, reductions in food intake; and feelings of indignity from resorting to deplorable ways of obtaining food (Coates et al., 2007). HFIAS measures include; whether any household was worried their food supply would run out, whether any household member slept hungry due to inadequate food, whether any household member ate fewer times due to inadequate food and whether any household member could not eat their preferred food due to lack of

resources. HFIAS uses 9 indicators specific to a household's experience of food insecurity in the past four weeks. HFIAS approved standard scoring were used, where 1 = occurrence and 0 = non-occurrence. Zero indicated the measure of food insecurity never occurred, 1 described it rarely occurred (1-2 times), 2 described it sometimes occurred (3-10 times), and 3 described it often occurred (more than 10 times). The frequency of occurrence for each of the measures of a households' food security was combined to generate a total HFIAS score. An overall food insecurity score (from 0-27) was generated from the 9 questions such that households that answered 'no' were scored '0' (indicating non-occurrence) to all the nine questions and a maximum of 27 if all responses to the nine questions were 'yes' with frequency of occurrence being 'often' (Chakona & Shackleton, 2018). The household scores were categorized into a four-level ordered food security outcome consistent with the HFIAS guidelines (Coates et al., 2007b). The four levels comprised food secure (HFIAS = 0–1), mildly food insecure (HFIAS = 2–7), moderately food insecure (HFIAS = 8–11), and severely food insecure (HFIAS > 11).

The main independent variable is household decision-making arrangement. This variable is generated from a question that asked smallholder farmers to indicate the decision-making arrangement of their household (1 = male household head only, 2 = female household head only, 3 = joint household decision-making). Other covariates were structured into individual background information, household demographics and agricultural production and practice. These covariates include: age (0 = 18-25, 1 = 26-35, 2 = 36-45, 3 = 46-59, 4 = 60 and above); gender (0 = male, 1 = female); household size (0 = 1-4, 1 = 5-7, 2 = 8-11, 3 = 12 and above); marital status (0 = married, 1 = single, 2 = widowed/divorced); family structure (0 = extended family, 1 = nuclear family, 2 = family without husband, 3 = family without wife); marriage type (0 = monogamous, 1 = polygamous); source of credit (0 = no credit, 1 = formal, 2 = informal); wealth (0 = richest, 1 = richer, 2 = middle, 3 = poorer, 4 = poorest); education (0 = tertiary, 1 = no formal 2 = primary, 3 = secondary); post-harvest loss; cropping practice (1 = monocropping, 2 =

multiple cropping). We used the wealth index to measure household wealth. The wealth index is a composite measure of the cumulative standards of living of a household (Smits & Steendijk, 2015). We collected data on ownership of household assets such as mobile phones, moto-bikes, televisions, radio sets, type of building materials, toilet facility and access to water. We then created a continuous scale of household wealth based on ownership of the preset assets. The household wealth scores were further categorized into five wealth quintiles (i.e., richest, richer, middle, poor, poorest).

5.4.3 Analysis

There are three main analyses for this study. First, we used univariate analysis to understand the distribution of smallholder farmer household decision-making arrangement, food security and other livelihoods. Second, we estimated bivariate ordered logistic regression to assess the independent relationship between all predictors and food security. Finally, we estimated multivariate ordered logistic regression to examine the association between household decision making and food security. We used a nested regression model for the multivariate analysis and adjusted for individual background information, household demographics, and agricultural production and practices. The ordered/proportional odds logistic regression was appropriate because food security is an ordinal variable with four levels. The equation for the ordered/proportional odds logistic regression model is.

$$log\frac{P(Yij\leq 1)}{(1-P(Yij\leq 1)} = a_0 + \sum_{k=1}^{p-1}\left(a_{jk}\,X_{ijk} + V_{ij,}C = 1, \ldots . \Omega - 1\right) \quad \textbf{3}$$

Where $P(Yij \leq 1)$ indicates the probability that an event will occur. In this context, it represents the probability that a household is food secure (verses in mild, moderate and severe food insecurity). (1 - $P(Yij \leq 1)$ is the probability that the event will not occur, which represents the probability that a

household is not food secure and is therefore mildly, moderately or severely food insecure. *Xijk* = explanatory variables, (k=1) is the first explanatory variable and (*p*—1) is the last explanatory variable. *Vij* is the error term in the logistic model, α_0 and Ω - 1 are the intercept terms, and α_{jk} *is the* coefficient term (Hedeker et al., 2000). We checked for multicollinearity in the regression model using Variable Inflation Factor (VIF). All VIF values for the variables were less than 2.0, with an average VIF of 1.48, which indicates that variables used in the multivariate regression model are not highly correlated. The results of the regression models are shown in odds ratios (OR). ORs above one indicate a higher likelihood of households being food secure, and below one indicates less likelihood of being food secure.

5.5 Results

From the survey, more than half (75%) of the households reported that only the male household head made household decisions. Less than one-tenth (9%) of the households reported only female household heads made decisions and about 16% reported decisions were made jointly by household members (household head and spouse). Roughly 24% of the households were severely food insecure. About 30% were moderate food insecurity, 21% were mildly food insecure, and 25% were food secure. Majority of the participants were married (82%) with about 12% and 6% being single and divorced/widowed, respectively. The average farm size was 4.91 acres. Roughly 54% of households indicated they practiced multiple cropping, and about 46% indicated they practiced monocropping. Table 5.1 further indicates that, averagely farmers loss about 22% of their total harvest to PHL.

Table 5. 1: Descriptive statistics of smallholder livelihoods and food security in northern Ghana

Variables		Percentages (%)	No. of Responses
Household Decision Making	Male Household Head Only	75	830
	Female Household Head Only	9	93
	Joint Household	16	177
Food Security	Severely Food Insecure	24	258
	Moderately food Insecure	30	331
	Mildly Food Insecure	21	236
	Food Secure	25	275
Age	18-25	8	94
	26-35	20	216
	36-45	35	382
	46-59	31	338
	60+	6	70
Gender	Male	52	567
	Female	48	533
Household Size	1-4	16	175
	5-7	45	496
	8-11	27	296
	Above 12	12	126
Education	Tertiary	4	47
	Secondary	12	130
	Primary	17	184
	No formal	67	739
Marital Status	Married	82	908
	Single	12	128
	Widowed/Divorced	6	64
	Richest	19	206
Family structure			
	Extended	27	296
	Nuclear	70	762
	Family without husband	2	26
	Family without wife	1	15
Marriage type			
	Monogamous	83	747
	Polygamous	17	158
Wealth	Richest	19	206
	Richer	17	190
	Middle	22	248
	Poorer	22	238
	Poorest	20	218
Source of Credit	No Credit	54	597
	Formal	36	390
	Informal	10	113
Farm Size		4.91 acres	Min = 0, max = 30

Post-Harvest Loss (PHL)[1]		21.9	Min = 0, Max = 100
Crop Practice	Monocropping	47	511
	Multiple Cropping	53	584
Total Sample = 1100			

The bivariate ordered logistic regression in Table 5.2 revealed that households that practiced joint decision-making (OR = 1.48; p≤0.05) were significantly more likely to be food secure compared to households where only male household heads made decisions. Households with the primary farmer being single (OR = 0.71; p≤0.05) were significantly less likely to be food secure than households where the primary farmer was married. Also, Households with 5-7 (OR = 0.57; p≤0.001), 8-11 (OR = 0.33; p≤0.001) and above 12 (OR = 0.25; p≤0.001) members were significantly less likely to be food secure than household with 1-4 members. More so, Households with access to formal (OR = 0.25; p≤0.001) and informal (OR = 0.41; p≤0.01) credit were less likely to be food secure than households without access to credit. Education was significantly associated with household food security. Primary farmers with secondary (OR = 0.41; p≤0.001) and no formal (OR = 0.18; p≤0.001) education were less likely to be food secure than households with tertiary education. Poorer (OR = 0.42; p≤0.001) and the poorest (OR = 0.18; p≤0.001) households were also less likely to be food secure compared to the richest households. The results further showed that polygamous households (OR = 0.27; p≤0.001) had lower odds of being food secure compared to monogamous households. More so, all agricultural production variables were significantly associated with food security. Households that practiced multiple cropping (OR = 6.62; p≤0.001) were more likely to be food secure than those that practiced monocropping. A percentage increase in PHL (OR = 0.98; p≤0.001) significantly decreased the odds of being food secure.

[1] Proportion of harvested crops loss to spoilage or pest after harvest or during storage

Table 5. 2: Bivariate ordered logistics regression of food security and covariate

Covariates	**OR(SE)**	**95% CI**
Household Decision Making (ref: Male Household Head Only)		
Female Household Head Only	1.45(0.194)	0.988 - 2.117
Joint Household	1.48(0.161)*	1.078 - 2.022
Age (ref: 18-25)		
26-35	0.74(0.214)	0.485 - 1.124
36-45	0.43(0.203)***	0.292 - 0.646
46-59	0.78(0.205)	0.520 - 1.161
60 and above	1.71(0.280)	0.989 - 2.964
Gender (ref: Male)		
Female	0.64(0.109)***	0.515 - 0.789
Household Size (ref: 1-4)		
5-7	0.57(0.157)***	0.418 - 0.773
8-11	0.33(0.174)***	0.233 - 0.462
Above 12	0.25(0.215)***	0.164 - 0.380
Marital Status (ref: Married)		
Single	1.53(0.163)**	1.110 - 2.105
Divorced/widowed	1.84(0.224)**	1.184 - 2.854
Family structure (ref: Extended family)		
Nuclear	1.06(0.121)	0.838 - 1.346
Family with no husband	1.32(0.377)	0.631 - 2.765
Family with no wife	1.28(0.469)	0.509 - 3.208
Type of Marriage *(ref: Monogamous)*		
Polygamous	0.27(0.160)***	0.198 - 0.3716
Source of Credit (ref: No Credit)		
Formal	0.25(0.124)***	0.193 - 0.313
Informal	0.41(0.316)**	0.219 - 0.756
Education (ref: Tertiary)		
Secondary	0.41(0.316)**	0.219 - 0.756
Primary	0.68(0.305)	0.372 - 1.232
No Formal	0.18(0.288)***	0.105 - 0.324
Wealth (ref: Richest)		
Richer	0.92(0.181)	0.645 - 1.309
Middle	1.03(0.172)	0.735 - 1.440
Poorer	0.42(0.172)***	0.298 - 0.585
Poorest	0.18(0.181)***	0.128 - 0.260
Farm Size	1.00(0.008)	0.985 - 1.015
Cropping Practice (ref: Monocropping)		
Multiple Cropping	6.62(0.123)***	5.207 - 8.428
Post harvest loss (PHL)	0.98(0.007)***	0.965 - 0.992

* p<0.05, ** p<0.01, *** p<0.001, OR = Odds Ratio, SE = Standard Error, CI = Confident Interval

5.5.1 Multivariate analysis

Table 5.3 show findings for the nested multivariate ordered logistic regression. After controlling for individual background information in model 1, households where decisions are jointly made (OR = 1.66; $p \leq 0.001$) remained significantly more likely to be food secure compared to households where only male household heads made decisions, with a slight increase in odds ratio. In model 2, we controlled for smallholder household demographics and joint household decision-making (OR = 1.69; $p \leq 0.001$) was still a significant predictor of household food security. In model 3, we finally introduced agricultural production and practices and the relationship between joint household decision-making and food security remained consistent with a small increase of the odds ratio. In the final model (model 3), households with joint decision-making (OR = 1.71; $p \leq 0.01$) were 71% more likely to be food secure than households with only the male household head making decisions.

The predicted probabilities plot in Figure 5.2 further illustrates the relationship between household decision-making arrangements and food security. For example, Figure 5.2A shows that joint decision-making has the highest predicted probability of being food secure than single decision-making arrangements (only male HH or only female HH). Similarly, Figure 5.2D shows that joint decision-making has the lowest predicted probabilities of being severely food secure. Based on the results from the proportional odds logistic regressions and predicted probabilities we reject the null hypothesis that households that practice joint decision-making are not significantly more likely to be food secure compared to households that practice sole decision-making (specifically patriarchal sole decision-making).

Table 5. 3: Multivariate ordered logistics regression of food security and covariates

Covariates	Model 1		Model 2		Model 3	
	OR(SE)	CI	OR(SE)	CI	OR(SE)	CI
Household Decision Making (ref: Male Household Head Only)						
Female Household Head Only	1.17(0.230)	0.745 - 1.837	1.17(0.239)	0.734 - 1.875	1.13(0.250)	0.692 - 1.842
Joint Household	1.66(0.163)***	1.207 - 2.290	1.69(0.169)***	1.214 - 2.358	1.71(0.174)***	1.217 - 2.405
Age (ref: 18-25)						
26-35	1.02(0.245)	0.631 - 1.652	1.03(0.258)	0.624 - 1.717	1.27(0.270)	0.746 - 2.150
36-45	0.83(0.261)	0.499 - 1.391	1.26(0.274)	0.734 - 2.152	1.53(0.286)	0.875 - 2.685
46-59	1.68(0.267)	0.995 - 2.837	2.42(0.281)***	1.396 - 4.198	2.38(0.293)**	1.341 - 4.234
60 and above	3.38(0.340)***	1.736 - 6.589	4.11(0.355)***	2.053 - 8.239	3.33(0.366)***	1.626 - 6.818
Gender (ref: Male)						
Females	0.71(0.115)**	0.569 - 0.893	1.1(0.126)	0.863 - 1.412	1.2(0.128)	0.930 - 1.538
Marital Status (ref: Married)						
Single	1.21(0.211)	0.798 - 1.823	1.23(0.224)	0.795 - 1.916	1.3(0.236)	0.819 - 2.068
Divorced/widowed	1.68(0.277)	0.977 - 2.889	0.91(0.301)	0.503 - 1.637	0.94(0.310)	0.512 - 1.724
Education (ref: Tertiary)						
Secondary	0.43(0.328)**	0.224 - 0.808	0.41(0.346)**	0.206 - 0.800	0.42(0.355)**	0.211 - 0.847
Primary	0.73(0.311)	0.398 - 1.349	0.49(0.330)*	0.259 - 0.944	0.46(0.339)*	0.234 - 0.884
No Formal	0.17(0.299)***	0.094 - 0.303	0.16(0.315)***	0.086 - 0.295	0.18(0.323)***	0.097 - 0.343
Household Size (ref: 1-4)						
5-7			0.68(0.173)*	0.483 - 0.951	0.73(0.179)	0.515 - 1.040
8-11			0.47(0.205)***	0.315 - 0.704	0.54(0.212)**	0.358 - 0.821
Above 12			0.45(0.276)**	0.264 - 0.781	0.5(0.291)**	0.285 - 0.890
Family structure (ref: Extended family)						
Nuclear			0.66(0.154)**	0.490 - 0.895	0.65(0.159)**	0.474 - 0.885
Family with no husband			0.54(0.470)	0.215 - 1.357	0.67(0.479)	0.262 - 1.712
Family with no wife			0.55(0.554)	0.185 - 1.619	0.75(0.580)	0.241 - 2.344
Type of Marriage (ref: Monogamous)						
Polygamous			0.45(0.190)***	0.308 - 0.650	0.51(0.197)***	0.347 - 0.750
Wealth (ref: Richest)						
Richer			1.28(0.190)	0.881 - 1.858	1.29(0.194)	0.881 - 1.881
Middle			1.44(0.184)*	1.001 - 2.059	1.41(0.188)	0.974 - 2.031
Poorer			0.79(0.190)	0.544 - 1.144	0.93(0.194)	0.633 - 1.354
Poorest			0.39(0.202)***	0.260 - 0.574	0.37(0.211)***	0.247 - 0.565
Source of Credit (ref: No Credit)						
Formal			0.39(0.143)***	0.291 - 0.511	0.52(0.151)***	0.388 - 0.701

Informal		0.86(0.193)	0.589 - 1.252	0.75(0.194)	0.510 - 1.091
Farm size				1.02(0.027)	0.970 - 1.080
Cropping Practice (ref: Monocropping)					
Multiple cropping				4.87(0.141)***	3.691 - 6.420
Post-Harvest Loss (PHL)				0.96(0.010)***	0.942 - 0.979
Pseudo R^2	0.1689022	0.3362295		0.4369135	
Akaike Information Criteria (AIC)	2872.859	2674.635		2520.603	
Log likelihood	-1421.43	-1309.317		-1229.302	

* p<0.05, ** p<0.01, *** p<0.001, OR = Odds Ratio, SE = Standard Error, CI = Confident Interval

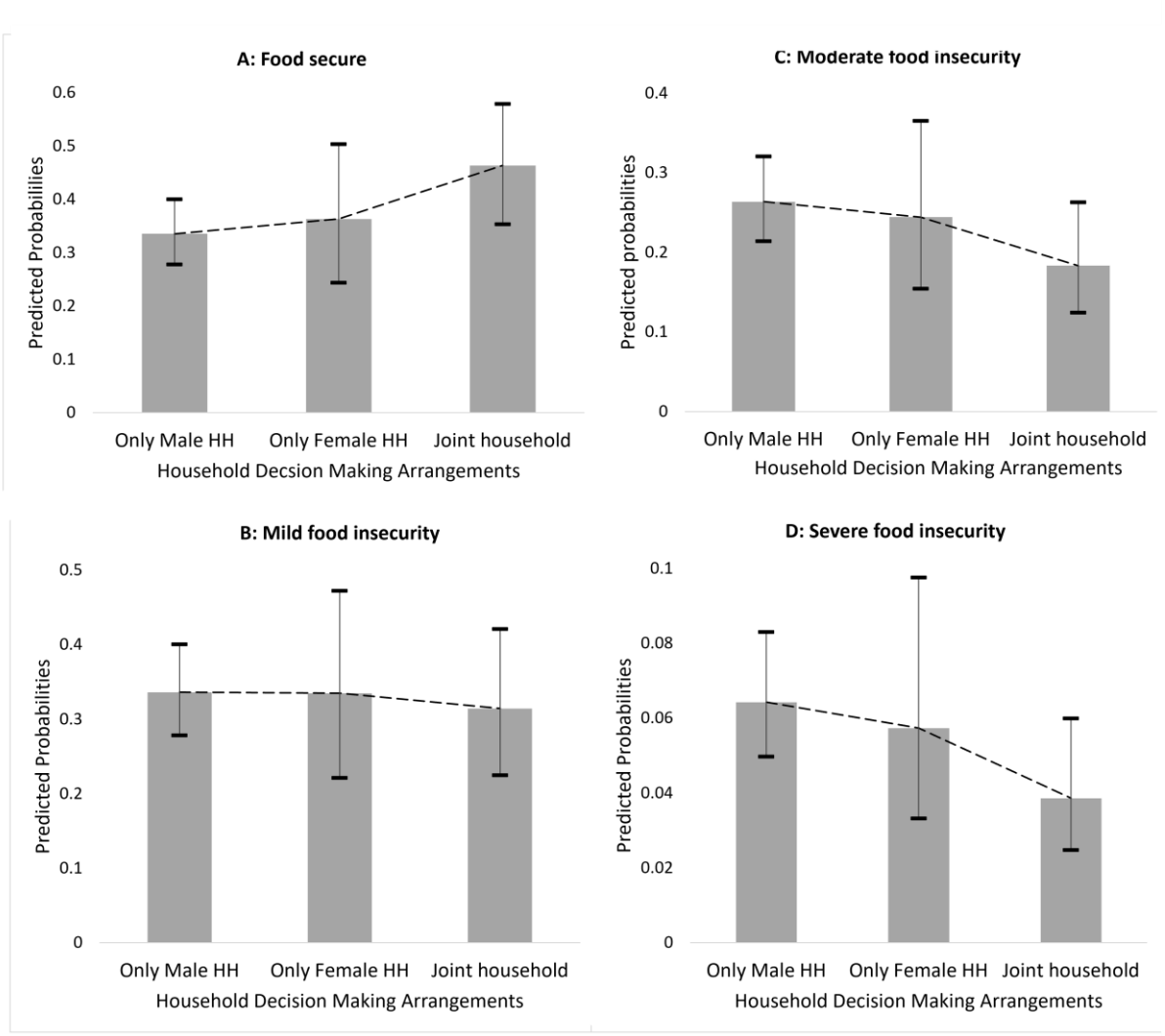

Figure 5. 2: Predicted probabilities (with confidence intervals) of food security adjusting for background information, household demographics and agricultural production and practice. Note: HH = Household Head

In the final model (model 3), there were other significant predictors of food security. Households where the primary farmer was within the age groups 46-59 (OR = 2.38; $p \leq 0.01$) or above 60 (OR = 3.33; $p \leq 0.001$), were more likely to be food secure compared to households where the primary farmer was within the age group 18-25. Households with 8-11 (OR = 0.54; $p \leq 0.01$) or above 12 (OR = 0.50; $p \leq 0.01$) members were less likely to be food secure compared to households with 1-4 members. Also,

Households where the primary farmer had secondary education (OR = 0.42; p≤0.01), primary education (OR = 0.46; p≤0.05), or no formal education (OR = 0.18; p≤0.001) were less likely to be food secure compared to households where the primary farmer had tertiary education. The poorest (OR = 0.37; p≤0.001) households remained less likely to be food secure compared to the wealthiest households. Also, polygamous households (OR = 0.45; p≤0.001), had lower odds of being food secure than monogamous households. All the agricultural production and practices introduced in model 3 were significantly associated with household food security. Multiple cropping (OR = 4.87; p≤0.001) significantly increased household chances of being food secure. And a unit increase in PHL (OR = 0.96; p≤0.001) significantly decreased the likelihood of households being food secure.

5.6 Discussions

We examined the association between intra-household decision-making arrangements and food security in northern Ghana. Overall, our findings show that joint household decision-making increases households likelihood of being food secure compared to sole patriarchal decision-making. Studies have demonstrated a link between decision making and household food security in smallholder context (see Aberman & Roopnaraine, 2020; Meijer et al., 2015; Stevano et al., 2020). However, a critical gap that remains less understood is how various intra-household decision-making arrangements are related to household food security outcomes. Building on earlier studies, we contribute to literature on the social determinants of food security by providing empirical evidence of the relationship between different household decision-making arrangements (sole and joint decision-making) and food security. Also, our study contributes to theory, specifically on intra-household bargaining models (i.e., unitary and collective models) and food security in rural contexts. We extend understanding on how cooperative intra-household decision-making may positively affect household food security outcomes as opposed to unitary household decision-making.

The observed association between joint household decision-making and food security can be understood through household collective bargaining and interdependency. Negotiation and reconciliation of different priorities among household members affect the efficient allocation and utilization of scarce household resources (Bjorvatn et al., 2020; Fiala & He, 2017). Thus, cooperation among household members is crucial for the fundamental welfare of the household. In joint household decision-making arrangements, collaboration and negotiation among household members may facilitate the effective and efficient allocation and utilization of household resources such as labor, land and capital. In joint decision-making arrangements, the dietary and nutritional needs of individual members may be well catered for as against sole patriarchal decision-making arrangements. In northern Ghana, men primarily control household productive resources partly due to structural gender roles and responsibilities (Kansanga et al., 2019). On the other hand, women play critical roles in the nutritional and dietary requirements of household members and as well as the provision of water. Men and women are therefore interdependent on their individual roles and responsibility for the welfare of the households. Structural norms and policy interventions in smallholder communities are evolving and increasingly support women's control over income in households (McCarthy & Kilic, 2017). Women have a higher tendency to spend resources on children and other members of the households, compared to men (Fiala & He, 2017; Haddad et al., 1997). In joint decision-making arrangements, resources are likely to be pooled from both decision makers (i.e., husband and wife) through cooperation and reconciliation of their bargaining powers and preferences. Therefore, collective household decision-making arrangements may increase household resources that are readily available for the basic needs of the household (e.g., food, water, shelter) compared to patriarchal sole decision-making arrangements. Also, there is a tendency of whimsical misappropriation of household resources with sole patriarchal household decision-making arrangements. For example, there is growing concern of alcohol abuse among men in northern Ghana, which may impair sound decision making (Fuseini et al., 2019; Luginaah & Dakubo, 2003). Therefore,

it is unreliable to leave crucial household decisions concerning food purchases, resources allocations, consumption and agricultural production to unitary patriarchal decision-making arrangements. Amid climate change stressors and food insecurity in northern Ghana, Joint household decision-making arrangements may help households leverage the roles, knowledge, skills and resources of household members to navigate crop failures and food insecurity.

Other household characteristics, socio-economic and agricultural production practices were found to be significantly associated with household food security. Larger households (i.e., number of people) were less likely to be food secure. The link between household size and food security can be understood through dependency burden and stress on household resources. In rural communities, many household members may not necessarily translate to high farm labor (Titus & Adetokunbo, 2007). High number of household members may be detrimental to household resources if the household does not possess the requisite additional resources in the form of capital and farmlands to put the labor into use. Also, many households may rather indicate a higher dependency ratio, especially if most of the household members are within ages below the active workforce or incapacitated and unable to contribute to production. This also explains the finding that polygamous households were less likely to be food secure compared to monogamous households. Polygamous marriages often translate to larger households and high dependency burdens. In monogamous marriages and smaller families, the dietetic needs of individuals members may be catered for more appropriately and effectively compared to polygamous and larger family sizes, respectively.

Consistent with (Atuoye et al., 2019; Krishna Bahadur et al., 2018; Atuoye et al., 2017), the poorest farmers were less likely to be food secure than wealthier farmers. Wealth may directly improve household food security through purchasing power. Impoverished farmer may lack cash or assets (that could be sold or barter traded) to purchase food, especially in the dry season when most households have

exhausted their stored harvest. Wealth is also an essential mediating factor in the access of productive resources such as land, labor, machinery and climate information for agricultural production (Kuntashula et al., 2015). In northern Ghana, the erratic nature of rainfall demands that farmers cultivate and plant timely to avoid crop failure (Kansanga et al., 2019). Therefore, command over productive resources is marked mainly by competition. With the increasing shortage of manual labor and the associated increase in labor wage and expensive farm machinery (Fisher & Kandiwa, 2014), impoverished farmers may be at a competitive disadvantage in accessing these resources for timely cultivation.

Agricultural production and practices such as type of cropping and post-harvest food loss were also significantly associated with household food security. Findings showed that farmers that practiced multiple cropping were more likely to be food secure compared to mono-cropping. This finding is consistent with studies suggesting that multiple cropping improves soil fertility and guards against crop failure (Li et al., 2019; Mukadasi, 2018). Multiple cropping suppresses soilborne pathogens that are even resistant to fungicides and reduces the activities of pests (Klimek-Kopyra et al., 2017; Wahbi et al., 2016). For example, cereals (e.g., maize) are intercropped with legumes (e.g., soybean) in northern Ghana (Nyantakyi-Frimpong & Bezner-Kerr, 2015). This practice increases organic matter production and leaf photosynthesis (Li et al., 2019). Multiple cropping can also rejuvenate and increase the production capacities of unfertile lands (Kansanga et al., 2021; Beets, 2019). More so, multiple cropping is a form of crop risk diversification. The rationale for multiple cropping as a risk diversification strategy is that should one crop fail, farmers may rely on other crop that are resistant to climate stressors, pest and diseases. Our findings further indicated that increase in post-harvest loss adversely affect household food security, which concurs with (Irani et al., 2018; Shafiee-Jood & Cai, 2016). Post-harvest loss represents a direct removal of food from household food reserves. Post-harvest loss is especially crucial in smallholder farming communities because households draw most of what they consume from what they

have cultivated and stored. Post-harvest loss also decreases available food supply, which may lead to food price hikes and a compromise in the affordability facet of food security (FAO, 2009).

Though our findings offer useful insights into understanding the role of household decision-making arrangements in household food security, the study has some underlying limitations worth noting. Food security is computed from self-reported measures. Therefore, there is a likelihood of response bias. Measures of food security outcomes are based on recall of the past four weeks. Thus, participating primary farmers may have understated or overstated their food security outcomes due to their inability to recall such events accurately. Similarly, intra-household decision-making is a self-reported measure and equally subjected to response bias. Household food security outcomes are multi-faceted and shaped by numerous underlying factors. Considering this, the food security outcomes and experiences of different household members may differ. Our study was unable to capture such intra-household difference. The study is also based on cross-sectional data, which may limit our findings to statistical associations. Future studies may benefit from using longitudinal studies that may be able to assess the causal relationship between household decision-making arrangements and food security.

5.7 Conclusion and recommendations

Our study shows that joint household decision-making arrangements may positively affect household food security outcomes than sole patriarchal decision-making arrangements in smallholder farming communities. Based on these findings, we suggest that policies and programs that seek to address food insecurity in smallholder communities must first acknowledge the role of intra-household decision-making on food security outcomes. Some household policy interventions assume that increasing benefits to household heads (predominantly male) in rural areas translates to a trickle down of such benefits to wives, mothers and children. Such premises have been proven to be flawed and policy interventions based on this had often failed. Similarly, contemporary policies on gender relations often implicitly

signify a focus on women. Such initiatives primarily aim to empower women by targeting them for training, funds and agricultural extension services. However, these initiatives have proved more difficult to yield the desired results without the involvement of males (Doss, 2017). The unsatisfactory outcomes of these initiatives indicate a misunderstanding and a simplistic view of how gender relations in decision making affect household food security initiatives (Kawarazuka et al., 2017). This reinforces the need to focus on the interdependence and complementarity of men and women in household food security interventions. Therefore, women empowerment must be pursued alongside cooperation, negotiations and reconciliation of power and preferences in households. This should be based on gender transformative approaches that focus on women's and men's agency rather than interventions aimed at abruptly changing cultural norms.

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Chapter 6

6 Conclusion

6.1 Introduction

This thesis explored the potential of smallholder livelihoods strategies in improving climate change resilience and food security in smallholder context. Specifically, this thesis examines the impacts of livelihood diversification strategies and decision making on smallholder farmers resilience to climate change and food security, respectively. This chapter summarizes the main findings of this thesis based on the two main objectives. It presents the contribution of this thesis to the literature on food security and climate change resilience. It also outlines how the study contributes to discussions on intra-household bargaining and food security. This chapter further summarizes the policy implication of the study findings. Lastly, the chapter highlights some of the limitations of this research, and outlines directions for future research.

6.2 Summary of findings

6.2.1 Objective one: Livelihood diversification strategies and resilience to climate change

I examined the relationship between livelihood diversification strategies and resilience to climate change in semi-arid Ghana. Detailed findings of this objective are found in chapter 4. The outcome variable was households' resilience to climate change and the key predictor variable was livelihood diversification strategies. Given that the outcome variable was ordered, I used the ordered logistic regression to examine the association between the predictors and resilience to climate change.

Results from the multivariate logistic regression showed that farm/agricultural diversification was significantly associated with households' resilience to climate change. Smallholder livelihoods are mainly reliant on the production and trade of agricultural goods and other ecosystem services. For this

reason, farm livelihood diversification strategies can help ensure risk spreading. Recently, there is a growing demand for high-value agricultural produce (e.g., fruits, meat, vegetables, fish, and eggs) in urban and peri-urban areas. This demand offers opportunities for smallholder farmers to diversify into farm livelihoods such as poultry, vegetable gardening and fishing for extra income. Similarly, a synchronized diversification into both farm and non-farm livelihood was found to be associated with resilience to climate change. This finding contributes to the empirical knowledge gap in the role of farm and non-farm livelihood strategies in climate change adaptation and resilience in smallholder communities. This finding demonstrates that a concurrent diversification into both the farm and non-farm livelihood may facilitate the inflow of resources between the two livelihood activities. Compared to farm livelihoods, non-farm livelihood strategies are capital intensive (Barrett et al., 2001). In northern Ghana, where credit is not readily accessible, revenues from on-farm diversification may be used as capital for non-farm livelihood activities. Symbiotically, capital gains from non-farm livelihoods may be used for coping and adaptation strategies in farm/agricultural activities. In smallholder context, non-farm livelihoods are more beneficial when it supplements farm livelihood strategies (Babatunde, 2013; Pfeiffer et al., 2009). Thus, synchronous diversification into farm and non-farm livelihoods can be crucial in facilitating the inflow of resources between farm and non-farm livelihood adaptations in smallholder communities.

6.2.2 Objective two: Intra-household decision making arrangement and food security

Climate change and food insecurity are related problems in northern Ghana. For the second objective, I examine the relationship between intra-household decision-making arrangements and food security using an ordered logistic regression. Findings showed that joint decision-making increased households' likelihood of being food secure compared to sole patriarchal decision-making arrangement. In northern Ghana, household decision making is primarily a function of males as per gender norms and values

(Kansanga et al., 2019). Such structural gender norms have limited the participation of women and children in household decision making. Through household bargaining models, this study explains how the involvement of all household members in decision making may improve food security in smallholder communities.

When all household members are involved in the decision-making process, they are more likely to negotiate and reconcile their different preferences and effectively allocate resources to meet their collective and individual needs (Bjorvatn et al., 2020). Amid multiple-interacting environmental and socio-economic stressors, joint household decision-making arrangements may be more useful in navigating such stressors than patriarchal decision-making arrangements. The welfare and good functioning of households rely on the interdependence of their individual roles and responsibilities (e.g., the different functions men and women play in the household). In joint decision-making arrangements, resources are likely to be pooled from both husband and wife through cooperation and reconciliation of their bargaining powers and preferences. Therefore, increasing household resources available for the household's basic needs (e.g., food, water, shelter) than patriarchal sole decision-making arrangements.

6.3 How the manuscripts integrate

The manuscript examines smallholder livelihoods in the context of climate change and food insecurity. Chapter 4 examined the association between livelihood diversification strategies and resilience to climate change. The chapter demonstrates that farm and non-farm livelihoods are concurrent and complementary livelihood strategies that can ensure the inflow of resources between the two livelihood adaptations, especially in resource-constrained settings like northern Ghana. Chapter 5 examined a related problem. It examined how social factors such as household decision-making arrangements continue to shape household food security outcomes. The chapter demonstrates that joint household decision-making arrangements may help households leverage household members' roles, knowledge,

skills, and resources to navigate crop failures and food insecurity. Collective decision-making can also enforce livelihood adaptation strategies in smallholder contexts through the complementarity of household livelihoods. Together, these two manuscripts explore smallholder livelihoods amid climate change and food insecurity in northern Ghana.

6.4 Contributions of the study

This study contributes to the literature on climate change and food insecurity in smallholder communities in SSA. First, the study highlights the importance of farm and non-farm livelihood adaptation strategies in building climate change resilience among smallholder farmers in SSA. The findings from this study published in the journal Climatic Change, are consistent with earlier work in similar contexts (e.g., Asravor, 2018; Dapilah & Nielsen, 2019; Tsiboe et al., 2016; Haggblade et al., 2007; Barrett et al., 2001). However, we still understand little about opportunities within farm livelihoods or harnessing synergies between farm and non-farm livelihoods for risk-spreading. This study extends the literature by providing empirical evidence on how synergies between farm and non-farm livelihood could be harnessed to improve climate change adaptation and resilience. The study demonstrates that farm and non-farm livelihoods can be synchronized and complementary livelihood strategies that may facilitate the inflow of resources between the two livelihood adaptations (i.e., farm and non-farm), especially amid inaccessible capital in northern Ghana. The study also provides a nuanced understanding of the opportunities within farm livelihoods strategies. I argue that smallholder farmers can take advantage of the growing demand for high-value agricultural produce (e.g., eggs, vegetables, meat) to provide additional income and support.

Additionally, the study contributes to the literature on the socio-cultural determinants of food security in SSA. Discussions on food security have focused mainly on the biophysical (i.e., temperatures, soil, precipitation, pest and diseases) and economic (i.e., prices, income) constraints of

food production. This study provides empirical evidence of the relationship between various household decision-making arrangements and household food security outcomes. Multiple studies have demonstrated a link between intra-household decision-making arrangements and household food security outcomes in smallholder context (see Aberman & Roopnaraine, 2020; Meijer et al., 2015; Stevano et al., 2020). This study broadens understanding of how cooperative intra-household decision-making arrangements may positively affect household food security outcomes instead of unitary household decision-making (i.e., sole patriarchal decision-making arrangements).

This thesis also contributes to theoretical developments on feminist economics and household bargaining theories. I argue that collective household bargaining arrangements may facilitate the negotiation and reconciliation of different household preferences to improve household food security compared to unitary household bargaining. Unitary household models represent an oversimplification of the complexity of the household as a bargaining unit, where members may have diverse preferences. The underlying principle of the unitary model is that all household resources are put together and allocated by a single household head in the interest of all household members, which reflects the patriarchal system in Ghana (Kansanga et al., 2019; Haddad et al., 1997). However, it has inherent challenges as individual members of a household cannot at all times have the same or aggregated preferences (Lundberg & Pollak, 2016). Collective bargaining models involve multiple decision-makers who negotiate their different choices to achieve optimal resource allocation and satisfaction of household needs. Therefore, collective bargaining accurately represents multi-member households and may be essential in improving household food security outcomes.

6.5 Policy recommendations

Findings from this thesis have vital policy implications. Based on the results, I suggest that agricultural and development policies must be broadened to include critical issues such as livelihood diversification.

In northern Ghana and similar context in SSA, synchronized diversification into agricultural and non-agricultural livelihood adaptations may prove more beneficial to climate change resilience. Policies that seek to improve smallholder agriculture must be pursued alongside building the skills of smallholder farmers to help them diversify production into agricultural and non-agricultural livelihood strategies. Doing this will be crucial in harnessing the risk spreading role of livelihood diversification strategies to address the underlying poverty, food insecurity and climate change stressors in smallholder communities in SSA. Such policy direction must be pursued alongside relevant underlying factors, including providing adequate and timely climate information, indigenous knowledge systems and farm management.

Further, findings from this study suggest that policies and programs that aim to address food insecurity in smallholder communities need to acknowledge the role of different decision-making arrangements. In patriarchal societies, joint household decision-making arrangements may be beneficial for household food security outcomes. Policy directions in smallholder communities have implicitly assumed that directing resources to male household heads will lead to a trickle-down of resources to other household members (e.g., women and children). However, policies based on such unitary principles have proved to be ineffective. Similarly, current policy interventions overly focus on women empowerment, consequentially, such initiatives have not often yielded the desired results (Doss, 2017). According to Kawarazuka et al. (2017), the unsatisfactory outcomes of these initiatives represent a misunderstanding and simplistic view of how decision-making arrangements affect household food security outcomes. Hence, there are calls for a paradigm shift where policies focus on the interdependence and complementarity of men and women in household food security outcomes. Therefore, I suggest that women empowerment must be complemented with cooperation, negotiations and reconciliation of power and preferences in the household among men and women.

6.6 Study limitations

Though the study offers numerous contributions as highlighted above, some limitations of the study are worth stating. First, the study used a cross-sectional survey to examine smallholder livelihoods in the context of climate change and food insecurity. The use of quantitative methods limits our findings to statistical associations. Also, the study used self-reported measures to capture climate change resilience. This means there is a likelihood of response bias. Similarly, questions used to compute household food security were based on a recall period of four weeks. Thus, the reported measures of household food security outcomes may have been overstated or understated by participating farmers due to their inability to accurately recollect such events. Further, primary farmers reported the different livelihood strategies of household members, however, not all livelihood activities may be known to the primary farmer. Therefore, there is the potential for an overestimation or underestimation of household livelihood activities. Also, income from various farm and non-farm livelihood strategies are essential in determining how they contribute to households' adaptive capacity and resilience to climate change (Atuoye et al., 2019; Barrett et al., 2001). However, the absence of reliable secondary data on the income of smallholder households and the inherent challenges in capturing such data using primary data collection methods meant that the study could not capture the income differences from the various livelihood activities.

More so, food insecurity and resilience to climate change are multi-faceted and shaped by numerous underlying determinants. Thus, food insecurity and resilience to climate change can be a differentiated experience even within the same household in smallholder context. Since the study survey was at the household level, it could not capture the intra-household differences in food insecurity experience and adaptive capacities. Similarly, climate change resilience is based on the perceptions of primary farmers on how the household can handle climate change stressors. However, the perception of

the primary farmers may not be an accurate representation of individual members' perceived resilience to climate change.

Notwithstanding these limitations highlighted, findings from the study still offer a valuable understanding of how smallholder livelihoods and decisions affect climate change resilience and food security, respectively. The statistical associations that were found between various variables offer insights on; (i) how livelihood diversification strategies can be leveraged to improve resilience to climate change among smallholder farmers and (ii) how intra-household decision-making arrangements affect household food security outcomes. Findings from this thesis remain relevant for policy directions in smallholder communities in northern Ghana and similar contexts in SSA.

6.7 Implication for future research

Given the findings and the inherent limitations of the study, I suggest some opportunities for future research. The study employed quantitative methods to examine smallholder livelihoods amid food insecurity and resilience to climate change with the household as the unit of analysis. The use of the household as a unit of analysis limits the understanding of individual voices and experiences of food insecurity and climate change stressors. The use of qualitative methods would unearth the in-depth food security experience of individual household members. Qualitative methods would help reveal the perceived climate change resilience of individual household members. Also, some significant predictors (e.g., post-harvest loss, religion, farm power, marriage type, household size, climate information) of food security and resilience to climate change emerged in the results. This points to the need for qualitative methods to investigate how these factors affect household food security outcomes and resilience to climate change in smallholder communities.

The role of livelihood diversification strategies on resilience to climate change would be better understood if income from the various livelihood strategies are known. Though capturing income data

on smallholder income remains challenging, it is crucial for future studies to capture smallholder income from various livelihoods. This will be useful in understanding the role of individual livelihoods on resilience to climate change. Also, it would be highly beneficial for future studies to examine how the synergies between different livelihood strategies (i.e., farm and non-farm) may improve food security and resilience to climate change in smallholder context using qualitative and longitudinal studies. More so, the use of quantitative methods may have limited our findings to statistical association. Therefore, future research may employ longitudinal study designs to understand the causal relationships between smallholder livelihoods, food security and resilience to climate change. For example, longitudinal study designs on the effect of smallholder livelihood diversification strategies on climate change resilience will help identify the extent to which livelihood diversification initiatives may impact smallholder climate change resilience and food security outcomes.

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Appendices

Appendix A: Research Ethic Approval: Farmer Livelihoods and Agricultural Production (FLAP)

Western Research

Date: 2 July 2019

To: Dr. Isaac Luginaah

Project ID: 114075

Study Title: Using participatory scenario planning to understand community seed systems resilience to climate change in Ghana and Malawi Region

Short Title: Climate change and seed security in Ghana and Malawi

Application Type: NMREB Initial Application

Review Type: Delegated

Full Board Reporting Date: August 2 2019

Date Approval Issued: 02/Jul/2019

REB Approval Expiry Date: 02/Jul/2020

Dear Dr. Isaac Luginaah

The Western University Non-Medical Research Ethics Board (NMREB) has reviewed and approved the WREM application form for the above mentioned study, as of the date noted above. NMREB approval for this study remains valid until the expiry date noted above, conditional to timely submission and acceptance of NMREB Continuing Ethics Review.

This research study is to be conducted by the investigator noted above. All other required institutional approvals must also be obtained prior to the conduct of the study.

Documents Approved:

Document Name	Document Type	Document Date	Document Version
FLAP Survey Ghana June 13, 2019	Online Survey	13/Jun/2019	2
FLAP Survey Malawi June 13 2019	Online Survey	13/Jun/2019	1
Focus Group Letter of Information and Consent Ghana June 25 2019	Verbal Consent/Assent	25/Jun/2019	2
Focus Group Letter of Information and Consent Malawi June 25 2019	Verbal Consent/Assent	25/Jun/2019	1
Ghana Participatory Scenario Planning Activities May 24 2019	Focus Group(s) Guide	24/May/2019	1
Letter of Invitation Farmers Ghana June 25 2019	Recruitment Materials	25/Jun/2019	2
Letter of Invitation Farmers Malawi June 25 2019	Recruitment Materials	25/Jun/2019	2
Malawi Participatory Scenario Planning Activities June 25 2019	Focus Group(s) Guide	25/Jun/2019	1
PSP Participants Characteristics Data Collection Sheet Ghana Malawi June 25 2019	Other Data Collection Instruments	25/Jun/2019	1
RA_Confidentiality Agreement Ghana and Malawi - June 25 2019	Verbal Consent/Assent	25/Jun/2019	2
Recruitment Letter of Invitation Focus Groups Ghana June 25 2019	Recruitment Materials	25/Jun/2019	2
Recruitment Letter of Invitation Focus Groups Malawi June 25 2019	Recruitment Materials	25/Jun/2019	2
Verbal Letter of Information and concent Farmers Ghana June 25, 2019	Verbal Consent/Assent	25/Jun/2019	2
Verbal Letter of Information and consent Farmers Malawi June 25 2019-1	Verbal Consent/Assent	25/Jun/2019	1
Written Letter of Information and concent Farmers Ghana June 25, 2019	Written Consent/Assent	25/Jun/2019	1

Written Letter of Information and consent Farmers Malawi June 25 2019	Written Consent/Assent	25/Jun/2019	1

No deviations from, or changes to the protocol should be initiated without prior written approval from the NMREB, except when necessary to eliminate immediate hazard(s) to study participants or when the change(s) involves only administrative or logistical aspects of the trial.

The Western University NMREB operates in compliance with the Tri-Council Policy Statement Ethical Conduct for Research Involving Humans (TCPS2), the Ontario Personal Health Information Protection Act (PHIPA, 2004), and the applicable laws and regulations of Ontario. Members of the NMREB who are named as Investigators in research studies do not participate in discussions related to, nor vote on such studies when they are presented to the REB. The NMREB is registered with the U.S. Department of Health & Human Services under the IRB registration number IRB 00000941.

Please do not hesitate to contact us if you have any questions.

Sincerely,

Kelly Patterson, Research Ethics Officer on behalf of Dr. Randal Graham, NMREB Chair

Note: This correspondence includes an electronic signature (validation and approval via an online system that is compliant with all regulations).

Appendix B: Survey topics and number of item/questions

Survey Topic	Number of Questions (Sub-questions)
Background information	10
Household demographics	10
Agricultural production and practices	45
Household food security	1(14)
Household expenditure	1(10)
Livestock	2 (6)
Livelihood activities and other income	3
Access to credit	5
Household assets	1
Housing and amenities	6
Household gender relations	17
Adaptative capacity and resilience	5

Source: FlAP survey, Upper West Region 2019

Appendix C: Survey Instrument

A FARMER LIVELIHOOD AND AGRICULTURAL PRODUCTION (FLAP) SURVEY

INTRODUCTION

Informed Consent. ENUMERATOR, PLEASE READ THE FOLLOWING TO THE RESPONDENT

My name is _____. I am working for the Department of Geography at the Western University in Canada and University of Denver and Cornel University in the United States of America. We would like to understand more about your family and farming practices. I would like to ask you if I might interview you, and I'd like to explain more about what will be involved. Please feel free to ask any questions at any time. The results from this study will be used to inform future initiatives aimed at improving farmers' food security and agrobiodiversity.

If you agree to participate in this part of this study, we want to learn from your knowledge and how you are farming. We will be spending about an hour asking you questions about your cropping practices, your diet and other information that affects your family's food security. There is no right or wrong answer to our questions. If you feel uncomfortable at any moment or would prefer that I not participate/observe certain activities, you can refuse my presence at any time.

There is no direct benefit to you for participating in this part of research; however, it will help you to get to know us and become familiar with our study and provide an opportunity for you to express any concerns that you have regarding your life as a farmer. Additionally, the knowledge gained in this study will benefit your community indirectly. We will share what we learn from your farming practices with local, national and international institutions such that it can be used to inform initiatives for improving food security for smallholder farmers. You will not incur any costs by participating in part of the study other than about an hour spent discussing things with us. You will not receive any payment for this time.

Your participation in this study is completely voluntary and you may refuse to participate or leave the study at any time. Your name will only be recorded to document that you have agreed to participate in this research. It will not be put in any of the project documents to be prepared from this research. Only the research team will have access to the data provided and records will be kept safely in a locked cabinet to which only the research team will have a key, to ensure no one apart from the study investigators can have access to them. The survey will take about an hour.
Do you agree to continue with the survey? ☐ YES ☐ NO

You are encouraged to ask me questions at any time during or after this study, Thank you for all your help and cooperation with this study.

1.1 Name of Enumerator: _____

1.2 Date of assessment: _____

1.3 Village name _____

BACKGROUND INFORMATION

Respondent Information

1.1 . Respondent number:

1.2 . Age: _____ (years)

1.3 Gender (Sex): ☐ Male (1) ☐ Female (0)

1.4 Relationship: ☐ Household head (1) ☐ Spouse (2) ☐ Son/daughter (3) ☐ Other living in HH (4)

1.5 Education ☐ No formal (1) ☐ Primary school (2) ☐ Secondary (3) Tertiary (4)

1.6 Marital status ☐ Single (1) ☐ Married (2) ☐ Divorced (3) Widowed ☐ (4).

1.7 . If married, what is your marital structure ☐ Monogamous ☐ Polygamous

1.8 . Religion ☐ Christian (1) ☐ Muslim (2) ☐ African Traditional Other ☐ (4)……...

1.9 . Ethnicity ☐ Dagao (1) ☐ Sisaala (2)

Household Demographics

1.10 Which of the following best describes the structure of your household?

a	Female centered (No husband/male partner in household, may include relatives, children and friends)	
b	Male centered (No wife/female partner in household, may include relatives, children and friends)	
c	Nuclear (Husband/male partner and wife/female partner with or without children)	
d	Extended (Husband/male partner and wife/female partner with or without children and relatives	
e	Child centered (Child-centered)	
f	Other	

1.11 Gender of household Head (HH).

☐ Male (1) ☐ Female (0)

1.12. Residential status of the household (HH). To be revised or omitted if there is no distinct category

☐ Resident (1) ☐ Returnee (2) ☐ Refugee (3)

1.13 For how long have you continually lived in this area? _____ (years)

1.14 Household size: How many people live in this household? Specify the number under each age group below

Age group→	< 5 years	5-17 years	18-35 years	36-60 years	>60 years

1.15. How many household members are involved in Agricultural activities?

Module A: AGRICULTURAL PRODUCTION AND PRACTICES

The next questions ask about the land your household uses for agriculture. I mean all the land that your household used for agriculture in all the agricultural seasons in which your household planted crops during the **[season].**

Crop Production/ Seed System Profile

A.1 What crops did you plant last season? (Retain/add/remove crop(s) based on most likely one to be found in the target areas. Modify the codes as well)

Cereals	☐ Sorghum =1	☐ Maize=2	Rice=3	
	☐ Finger millet =4	☐ millet =5 (pearl	☐ Wheat=6	☐ Teff = 7
Oilseed	☐ Groundnut=8	☐ Sesame=9	☐ Sunflower =10	
Pulses	☐ Beans=11	☐ Cowpea=12	☐ Green grams	
	☐ French beans = 14	☐ Pigeon peas = 15	☐ Soya = 16	☐ Dolicos = 17
RTB	☐ Cassava=18	☐ Sweet potato=19	☐ Potato=20	
	☐ Cocoyam =	☐ Yams = 22	☐ Banana	
Vegetable	☐ 21 Local	☐ exotic		

A2. Should be asked only if the household indicated that they planted vegetable:

A.2a for what Main purpose do you cultivate vegetables?

☐ Domestic (1) ☐ Commercial (0)

A.2b. If commercial, who decides on how the money is used?

Men (1) ☐ Women (2) ☐ Both (3)

A.3 Name the three most important crops you cultivate

1)
2)
3)

A.4 Did you change the main crop you used to produce in the last few years?

A.5 Main reason for change of area if yes (see codes below): For statistical analysis, var can be grouped into structural: logistics, environmental …

1 = Lack of land;
2 = Access to more land; 3 = Lack of labor force
4 = Access to more labor force; 5=Lack of seed
6=Better access to seeds
7=Free seed
8=Increase in seed prices
9=Decrease in seed prices

10=Decrease of produce price
11=Guaranteed selling price produce
12=Secure market
13=Increased need at household level
14 = Lack of tools and equipment
15= Replanting of seed

Crop production parameters				
		a	b	**B1b: Units codes** 1 = hectares 2 = acres -8 = Not applicable
A6	What is the total amount of land your household owns?	Quantity ||||.|||	Units ||	
A7	During the **[season]** , how much land did your household use for agriculture (including land that is owned, rented/leased in, and borrowed, i.e., used without payment)?	Quantity ||||.|||	Units ||	

A8.	Was the land your household used for agriculture during the **[season]** more, less, or about the same as the amount of land your household used for agriculture during the **[previous season]**? **(If "More", go to question B3)** **(If "Less", go to question B4)** **(If "About the same", go to question B5)**	||	1 = More 2 = About the same 3 = Less

		a	b
A9.	What were the two most important reasons you used more land? **(Go to question B5)**		

		a	b
A10.	What were the two most important reasons you used less land?		

B3a /b: Codes for planting more land	**B4a /b: Codes for planting less land**
1 = Wanted to increase production because of increased need (e.g., for increased household consumption increased expenses/income, etc.)	1 = Reduced production because of reduced need (i.e., smaller household, lower expenses/income, etc.)
2 = Wanted to increase production to meet new demand (for existing or new crops)	2 = Reduced production because you lost markets
3 = Had more own capital (not borrowed) to invest in agriculture (hire labor, rent/buy land, buy inputs, buy/rent equipment or draught power, etc)	3 = Had less own capital (not borrowed) to invest in agriculture (hire labor, rent/buy land, buy inputs, etc)
4 = Able to access more credit (c ash or in-kind) to invest in agriculture (hire labor, rent/buy land, buy inputs, buy/rent equipment or draught power, etc)	4 = Had access to less credit (cash or in-kind) to invest in agriculture (hire labor, rent/buy land, buy inputs, etc.)
5 = Had access to more land that you didn't have to pay for	5 = Did not have access to as much land that you didn't have to pay for
6 = Had access to more labor you didn't have	6 = Less household labor available (due to illness, smaller household, etc.)
	7 = La ck of access to as much draught power that you did not have to pay for

to pay for 7 = Had access to more draught power you did not have to pay for 8 = Could afford more inputs because they	8 = Could not afford as many inputs because of higher prices or lower subsidies 9= Lower prices for crops discouraged you from planting as much
were less expensive or more subsidized 9 = Higher prices for crops encouraged you to plant more 10 = More of the land you use for agriculture was useable (less damage from floods/weeds,etc.) ***11 = Began using land left fallow in previous year 12 = Other, 8 = Not applicable/ no other***	10 = Land became unusable (Flood/drought/Invasive weeds, etc.) 11 = Wanted to leave land fallow 12 = Other -8 = Not applicable/no other reason

A11. With which source of draught power did you cultivate the most land during the past 12 months?	| |	1 = Tractor 2 = Donkeys/Horses 3 = Cattle (cows & bulls) 4 = Other -8 = Not applicable/none

A12. I'd like to know how you divide agricultural work among household members and whether men and women have different responsibilities. Do the men or the women of the household do most of_____**[name of task from rows]** or is the work shared about equally among men and women?

		Crops kept for household consumption	Crops sold for c ash income
		a	b
1	Ploughing		
2	Hoeing		
3	Planting		
4	Weeding		
5	Applying fertilizer/pesticides		
6	Irrigation		
7	Harvesting		
8	Shelling/threshing maize/beans/ groundnuts/rice		
9	Post-harvest cleaning and sorting		
10	Marketing decisions (selling, transport to market, negotiating, etc.)		

B6a/b: Codes for source of labor:
1 = Female household members
2 = Male household members
3 = Shared among male and female household members 4
= Hired labor 6
= Other
-8 = Not applicable

The following questions ask about the crops your household planted or harvested during the **[season]**.

A13.	Season Enter names of (or codes for) the seasons relevant to the country	Which crops did you plant or harvest? See codes below	Did you intercrop this crop with another crop? 1 = Yes, 0 = No	How much area did you plant to this crop?	**Record area units**	How much_____did you harvest? Quantity **0 = None**	**Weight units**	**Weight of "other" in kg**	Of the seed you used to plant this crop, how much had you retained from your own production? 0 = None -7 = Don't know Quantity (kg)	If you had had to buy this seed, what would it have cost? -7 = Don't know Local currency	How much improved/certified seed did you buy to plant this crop? 0 = None -7 = Don't know Quantity (kg)	How much indigenous seed did you buy to plant this crop? 0 = None -7 = Don't know Quantity (kg)	**(Do not ask if j & k are both "0")** Considering cash and in-kind payments, what was the total amount you spent on indigenous and improved seed to plant this crop? Local currency
		a	b	c	d	e	f	g	h	i	j	k	l
	[first season] - if only one season, name it here and ask specifically about planting in this season.												
0													
1													
2													
3													
4													
	[second season] - if more than one season, name them in separate sections and ask specifically about planting in each season.												
5													
6													
7													
8													
9													

A14	For crops that are intercropped with other crops, record common expenses in the row corresponding to the first crop and do not record common expenses in the row corresponding to the second crop.	What was the cost of pesticides, herbicides, and spraying services you bought for this crop?	How much did you spend on non-labor expenses incurred to plant, tend, and harvest this crop (for example, e.g., leasing land or irrigating,)? **(Enter "0" if none)**	Did you hire any labor for this crop that you p aid based on the amount of time they worked? **(If "No" or 'don't know", go to next row/ crop)**	How many days of labor did you hire for preparing land, weeding, and harvesting for this crop? **(If "0", go to column r)**	Considering c ash, and the value of in-kind payment, what was the total amount you paid for this labor?	How many days of labor did you hire for other tasks for which you paid by the time spent for this crop? **(If"0", go to next crop)**	Considering cash, and the value of in-kind payment, how much did you pay for this labor?
		0 = None, -7 = Don't know	0 = None	1 = Yes 0 = No -7 = Don't know	Days of labor	Lo c al currency	Days of la bor	Lo c al currency
		m	n	o	p	q	r	s
		[first season] - if only one season, name it here and ask specifically about planting in this season.						
0								
1								
2								
3								
4								
		[second season] - if more than one season, name them in separate sections and ask specifically about planting in each season.						
5								
6								
7								
8								
9								

Season codes	**Crop codes**	**area unit codes**	**weight units codes**	
Develop c odes for each of the seasons using "1" for the main season, etc.	Insert codes for all staple and cash crops relevant to the country from the list of crop c odes in the Data Collection Manual.	1 = hectares 2 = acres 8 = Not applicable	1 = grammes = kilogrammes 3 = 100 kg bags = 90 kg bags	5 = 50 kg bags 6 = metric tonnes 2 7 = quintals 8 = Other 4

A15. During the **[season]**, did you pay any labor based on the task (for example, ploughing or transporting crops from the field to your house)? **(If "No" or "Don't know", go to question A17)** **(If "Yes", go to B9)**	|__|	1 = Yes 0 = No -7 = Don't know

A`16. Considering c ash and the value of in-kind payment, how much did you p ay for all these tasks?

A17.		Quantity (bags)	Weight units See c odes below	Weight of " other" units (kg)	Considering both cash and in-kind payments, what was the total amount you p aid for this fertilizer? Local currency
		a	b	c	d
	How much chemical and natural fertilizer did you buy for all the crops you planted last season?	| | | | |	| |	| | | | |	| | | | | | | |

: weight units codes

2 =	kilogrammes	5 =	50 kg bags
3 =	100 kg bags	6 =	metric tonnes
4 =	90 kg bags	7 =	quintals
		8 =	Other

The following questions ask about your sales of crops during the **[season]**.

A18	Season	Which crops did you harvest or sell during [season]? **(Include all crops listed in question B7a plus any other crops the respondent sold)**	How much of the quantity that you harvested have you sold, bartered, or used to repay loans?			What is the main reason you did not sell any of this crop?	Considering cash, the value of in-kind goods, and the value of what you bartered or used to repay loans, what was the total amount you received for what you sold?	Which member of the household made the decision about how (timing, buyer, price, etc.) to sell this crop?	What was the total value of all costs (both cash and in-kind) you incurred to sell this crop (e.g., transportation, storage, cleaning, drying, market fees, commissions, taxes, etc.)	Did you have any difficulty selling this crop?	What were the two most significant problems you had selling this crop?	
	Enter names of (or codes for) the seasons relevant to the country	Use codes from B7	Quantity **(If "0", go to e, Otherwise, complete c and d and then go to f)**	**Weight units**	**Weight of "other" in kg**	**(Go to next row/ crop or question)** See codes below	Local currency	See codes below		**(If "No", go to next row or next question)** 1 = Yes, 0 = No	See codes below	
	a a	a	b	c	d	e	f	g	h	i	j	k
	[first season] - if only one season, name it here and ask specifically about planting in this season.											
0												
1												
2												
3												
4												
	[second season] - if more than one season, name them in separate sections and ask specifically about planting in each season.											
5												
6												
7												
8												
9												

A19: Season codes	**B11c: weight units codes**	**B11e: Reasons for not selling**
Develop codes for each of the seasons using "1" for the main season, etc.	2 = kilograms 3 = 100 kg bags 4 = 90 kg bags 5 = 50 kg bags	1 = No surplus to sell 2 = Had surplus but did not need/want to sell 3 = Wanted to sell but price not attractive 4 = Had surplus, but no-one to sell crops to/no affordable access to markets

	6 = metric tonnes 7 = quintals 8 = Other	5 = Tried to sell but crop rejected due to poor quality 7= Have surplus to sell but waiting to sell it later 6 = Other

A19g: Decision maker codes 1 = Household head 2 = Spouse of household head 3 = Joint decision of household head and spouse 4 = Other		**A19j/k: Problems selling crop** 1 = High cost of transport to market 2 = Low prices in acaccessible markets 3 = High market fees/taxes 4 = Poor transportation infrastructure 5 = Trade restrictions (for example, restrictions on cross-border trade or restrictions on traders buying particular ccommodities) 6 = Not able to meet quality requirements of buyers 7 = Unpredictable prices 8 = Lack of price information 9 = Difficult/unable to find buyer 10 = Farmers' organization not effective at selling your commodities 11 = Late or slow payment from buyers 12 = Other -8 = Not applicable (no other problem)

The following questions ask about how your household used the [staples] commodities you harvested during the **[season]**.

A20.		Considering all the_____ **[name of crop]** that you harvested during the **[seasons]**, about what proportion did you… **(Use proportional piling if necessary) (Ensure that columns b through f sum to 100)**				

	Crop **(list all [staples] commodities harvested from question A13a)**	Sell, barter, use to repay loans, or give away?	Retain for sale later on	Lose to spoilage or pests during storage or use for other than its intended use <u>because</u> of spoilage?	Retain for consumption in your household?	Retain specifically for seed or animal feed?	What was the main cause of loss during storage?	How did you store the portion of this crop that you consumed in your household? **(Indicate up to two types of storage)**		How did you store the portion of this crop you sold (immediately or later on)? **(Indicate up to two types of storage)**		How did you usually dry this commodity?
		Percent	Percent	Percent	Percent	Percent	See codes below	See codes below	See codes below	See codes below	See codes below	See codes below
	a	b	c	d	e	f	g	h	i	j	k	l
1												
2												
3												
4												
5												

A21.	Did you dry this commodity adequately to reduce spoilage during storage?	Did you store the commodity in a structure that kept out rats, mice, and moisture?	Did you treat the commodity with chemicals during storage to control insect pests?	**Continue only for crops reported sold in column b**	Considering all the_____**[name of crop]** that you <u>sold</u> during the [seasons], about what proportion did you … **(Use proportional piling if necessary) (Ensure that columns p through r sum to 100)**			Of the portion of the _____ **[name of crop]** that you sold, about what proportion did you … **(Ensure that columns s and t sum to 100)**		**(Ask only if s > "0")** What was the main reason you sold some of this crop within four weeks of harvest?	Was there a market for a better quality than what you sold (i.e., lower moisture, less foreign matter, fewer small/ broken grains)? **(If "No", go to next row)**	What was the main reason you did not improve the quality for this buyer/ market?
					Sell to or through a farmers' organization?	Sell yourself at your farm gate?	Sell yourself somewhere other than at your farm gate?	Sell within four weeks of harvest?	Store and sell at a later date?			

	1 = Yes 0 = No	1 = Yes 0 = No	1 = Yes 0 = No		Percent	Percent	Percent	Percent	Percent	See codes below	1 = Yes 0 = No	See codes below
	m	n	o		p	q	r	s	t	u	v	w
1	__ |	__ |	__ |									
2	__ |	__ |	__ |									
3	__ |	__ |	__ |									
4	__ |	__ |	__ |									
5	__ |	__ |	__ |									

A21a: Crop codes	**A21g: Storage loss codes**	**A21h/ i / j / k: Storage options**	**A21l: Drying methods**
	1 = Mould /spoilage 2 = Pests/insects 3 = Rats/mice/etc. 4 = Other animals 5 = Other -7 = Don't know	1 = In traditional granaries 2 = Indoors – in basket/bags 3 = Indoors – open storage 4 = Outside – open storage 5 = In certified warehouses for which you received a receipt specifying the quality and quantity deposited 6 = In other warehouses/stores 7 = Metallic home silos (Latin America) 8 = Other -8 = Not applicable / did not store	1 = On the ground 2 = On tarpaulins or iron sheets 3 = On concrete / grain yards 4 = Mechanic al dryer 5 = Crib 6 = Hanging 7 = In the field (standing or stacked) 8 = Other -8 = Not applicable/did not dry

Reasons for selling at harvest	Reason for not improving quality
	1 = Needed immediate c ash 2 = Could not store 3 = Offered a good price 4 = Other	1 = Normal practice meets buyer specifications 2 = No increase in price to justify cost 3 = Increase in price not enough to justify cost 4 = Farmers' organization provided this service 5 = Do not have ability to dry, clean, or sort to buyer specifications 6 = Other

A22.		During the past 12 months, where did you get information about prices of staple commodities? **(Mark all that apply and prompt if necessary)**	**(Ask only if B13a = 1)** Did this information help you in your selling decisions?
		1 = Source of information 0 = Not a source of information -8 = Not applicable	1 = Yes 0 = No
		a	b
1	Radio/TV	__	_
2	Direct contact with traders	__	_
3	Farmers' organizations	__	_
4	Newspapers	__	_
5	Extension workers	__	_
6	SMS system/mobile phone	__	_
7	Neighbors/friends/relatives	__	_
8	Information boards at local agricultural offices	__	_
9	Personal knowledge of the market	__	_
10	Information from food reserve agency (country-specific name)	__	_
11	NGOs	__	_
12	International development organizations	__	_

A23. Did you cultivate any cash crops last season?

☐ No (1) ☐ Yes (2)

A23a. Did you grow crops in a backyard garden this past dry season?	Yes	1
	No	2
A23b. If yes, what was the size of the garden?	Area cultivated:	
A24. What crops did you grow in the garden? *Enumerator: Probe for all possible crops…*) Green leafy vegs, tomatoes, onions, potatoes, carrots, pumpkins, beans, maize, sweet peas, sweet potatoes, yams, sugar cane, cassava…	Crops:	
A25. What methods do you use to water the garden crops?	Diesel pump	1
		2
	Hand watering	3
	Gravity canals	4
	Deep planting/ residual moisture	5
	Other	97
A26. Did you grow any cash crops last season?	Yes	No
A27a. Did you receive a fertilizer coupon?		
A27b. If yes what quantity (specify in bags)?		
A28a. Did you apply any herbicide to your fields last season?		
A28b. If yes, what quantity?		

A29. Which of the following did you do to improve soil fertility

Strategy		Yes	No
Planted legumes			
Buried crop residue			
Agroforestry			
Mulching			
Prepared box ridges			
Planted vertiva grass			
Applied compost manure			
Crop rotation			
Other (specify)			
Applied chemical pesticides/herbicides/ fertilizers			
Other (specify)			

A30. Did you do any of the following to control pests and diseases?

Strategy	**Yes**	**No**	
Intercropped			
Crop rotation			
Improve soil fertility			
Applied botanical sprays (e.g. tephrosia, chisoyo)			
Planted repellant plants			
Physical killing			
Smash or burn beetles to apply to field			
Adjust planting time			
Applied chemical pesticides/herbicides/ fertilizers			
Other (specify)			

A31a. Have you shared any seeds in the last planting season?

☐ Yes ☐ No

A31b. if yes, check all of the crops which you have shared and indicate what amount

Crop	Quantity	
1.		
2.		
3.		
4.		
5.		
6.		

A32a. Have you received or borrowed any seeds in the last planting season?

☐ Yes ☐ No

A32b. If yes, specify source and quantity

Crop	Quantity	Source	
1.			
2.			
3.			
4.			
5.			
6.			

Module B: HOUSEHOLD FOOD SECURITY

Instructions to the Enumerators: For each of the following questions, make sure that you refer to the past four weeks. If the answer is 'yes', explain whether: sometimes (once or twice), often (3-10 times), frequently (more than 10 times).

#	Question (Check only one response). Each of the following questions applies to past 4 weeks.	Never	Rarely (1-2 times)	Sometimes (3-10 Times)	Often (More than 10 times)
B1	In the past 4 weeks, were you ever worried that you may not have enough food in your household?	☐	☐	☐	☐
B2	In the past 4 weeks was there anyone in this household unable to eat the kinds of foods you preferred because of a lack of resources?	☐	☐	☐	☐
B3	In the past four weeks did you or any household member have to eat a limited variety of foods due to a lack of resources?	☐	☐	☐	☐
B4	In the past four weeks was there any household member who had to eat some foods that you really did not want to eat because of a lack of resources to obtain other types of food?	☐	☐	☐	☐
B5	In the past four weeks was there anyone in this house hold who ate less amount of food [or a smaller meal than you felt you needed] because there wasn't enough food?	☐	☐	☐	☐
B6	In the past four weeks was there any household member who ate fewer times per day because there wasn't enough food?	☐	☐	☐	☐
B7	In the past four weeks was there ever no food to eat of any kind in your household because of lack of resources?	☐	☐	☐	☐
B8	In the past four weeks, did you or any household member go to sleep at night hungry because there wasn't enough food	☐	☐	☐	☐
B9	In the past four weeks was there any household member who had spent a whole day and night without eating because there wasn't enough food?	☐	☐	☐	☐
B10	Have you or any household member had to do 'byday' for food in the past 4 weeks because you have run out of your own food sources? Have you or any household member had to do ganyu for food in the past 4 weeks because you have run out of your own food sources?	☐	☐	☐	☐
	Enough clean water for home use?	☐	☐	☐	☐
	Enough fuel to cook your food?	☐	☐	☐	☐
	A cash income?	☐	☐	☐	☐
B11	Did you run out of food last year?	Yes or no			
B12	At what month after harvest did last season's produce finish and your household started struggling with finding food?	Indicate in months (July to September is the harvest season)			
B13	Does your household harvest/process shea to support household food provisioning?	Yes/no			
B12	What quantity of shea did your household harvest last year				

Dietary Diversity

B13. Now I will ask you questions about food stuffs and drinks that any household member ate or drank yesterday from the time he/she woke up until he/she went to bed *[Do not include food or drink taken elsewhere]*. Did any household

member eat or drink any of the following yesterday?

Food group	Examples	Yes	No
a) Cereals	Any food such as TZ, porridge, bread, spaghetti, scones, biscuits, rice, boiled whole maize grain, pito/sweet beer, or any food made from finger millet, sorghum, bulrush millet, maize and wheat?	1	0
b) Vitamin A rich tubers & vegetables	Any food such as: pumpkins, carrots or sweet potatoes having yellow pigment, including local orange maize? *[please check here if they indicate that they ate local orange maize]*	1	0
c) White tubers and roots	Any food in the group of: white sweet potatoes, coco yams, cassava, Irish potatoes, yams or any white roots and tubers?	1	0
d) Dark green leafy vegetables	Relish of dark green leafy vegetables as well as the indigenous vegetables including, Cat's whiskers leaves, cassava leaves, sweet potato leaves, mustard, rape, local rape, pumpkin leaves, cow peas leaves, bean leaves, black jack leaves	1	0
e) Any other vegetables)	Any kind of relish from leafy vegetables e.g. Chinese cabbage, okra, cabbage, egg plants, tomatoes, onions, green pepper and green beans?	1	0
f) Vitamin A rich fruits	Any fruits like papaya (pawpaw	1	0
g) Other fruits	Any other fruits including the indigenous wild fruits e.g. oranges, tangerines, lemons, tamarind, elephant fruits, avocado pears, bananas and baobab fruits?	1	0
h) Meats	, pork, goat meat, rabbit meat, mice, wild game, poultry duck, flying insects e.g. guinea fowl or any other bird, liver, kidney, heart, offal or any other meat.	1	0
i) Eggs	Eggs of any kind?	1	0
j) Fish	Fresh or dried fish	1	0
k) Legumes, nuts & seeds	Any type of beans and peas e.g. beans, cow peas, pigeon peas, nkhungudzu, peas, ground beans, soya beans, ground nuts, green gram, custard apple, Nseula, chick peas?	1	0
l) Milk and milk products	Milk and Food made from milk e.g. yoghurt, sour milk?	1	0
m) Oils and Fats	Any type of fats or oils e.g. cooking oil, animal fats and margarine used for cooking or added to food?	1	0
n) Sweets	Any sweet, sugar, honey, soft drinks such as Fanta, Coca-Cola, sprite, and other drinks to which sugar was added or sugary foods e.g. chocolate, sweets?	1	0
o) Coffee/tea	Any tea or coffee?	1	0

Module C. HOUSEHOLD EXPENDITURE

C1.	About how much did your household spend on_____for domestic consumption **during the last 30 days.** **(If "Don't know", go to next item)**				
1	Maize		9	Milk and dairy products	
2	Beans		10	Sugar/Salt	
3	Bread		11	Milling	
4	Rice		12	Alcohol & Tobacco	
5	Fruits & vegetables		13	Household items (soap, batteries, etc.)	
6	Fish/Meat/Eggs/ poultry		14	Transport and fuel	
7	Oil, fat, butter		15	Cooking & lighting fuel (wood, paraffin, etc.)	
8	Water		16	Soda/drinks (including tea)	

C3.	About how much did your household spend on_____**during the last 12 months**.
	(If "Don't know", go to next item) 0 = None
	Medical expenses, health care **-7 = Don't know**
	Education (books, school fees, uniform, etc.) Clothing, shoes
	(excluding those required for school) Equipment and tools
1	(including for agriculture) Construction, house repair
2	Debt repayment
3	
4	Celebrations, social events (funerals, weddings, etc)
5	Remittances/gifts
9	Raising crops (includes the cost of inputs – excluding equipment and tools - and labor) — — — —
10	Raising livestock (includes the cost of buying livestock, feed, and labor) — — — —

Module D. LIVESTOCK

D1. During the past 12 months, did your household raise any livestock, either for sale or for your own consumption? **(If "No", go to next section)**	|__|	1 = Yes 0 = No

D2.	What types of livestock has your household owned during the past 12 months?	How many of [animal type] do you have now?	How many of [animal type] did you buy during the past 12 months? **(If "0",go to e)**	Considering both c ash and the value of in-kind payments, how much did you spend purchasing these animals?	How many of [animal type] did your household consume or give aw ay during the past 12 months?	How many of [animal type] did you sell or barter during the past 12 months? **(If "0", go to h)**	Considering c ash and the value of in-kind payment, what is the total amount you received for the sale of these animals?	During the past 12 months, did you earn any money renting this animal or selling products from this animal? **(If "No", go to j)** **Yes=1, No=0**	In total, how much did you earn (in c ash and the value of in-kind payment) from renting these animals or selling their produces during the past 12 months?	Considering c ash and the value of in-kind payment, how much did you spend on feed for these animals during the past 12 months?	Considering c ash and the value of in-kind payment, how much did you spend on other costs for these animals such as veterinary supplies, taxes, and hired labor during the past 12 months?
	a	b	c	d	e	f	g	h	i	j	k
1											
2											
3											
4											
5											
6											
7											
8											
9											

Module E. LIVELIHOOD ACTIVITIES AND OTHER INCOME

E1	Other than agriculture and livestock that you've already told me about, **(mentioned in Modules Band D)**, what other sourcesof cash and in-kind income did your household have during the past 12 months? **(List top three livelihood sources first)**	How many members of your household worked at this activity during the past 12 months? **(Enter "not applicable" for remittances or gifts or other types of income that did not require work)**	Did the household incur any expenses with this activity? **(Probe about hired labor, purchasing items to sell, renting market space, transportation, etc.)**. **(If "No", go to next row/ activity)**	About how much were these expenses during the past 12 months?
		-8 = not applicable	1 = Yes 0 = No	
	a	b	c	
1				
2				— —
3				— —
4				— —
5				— —
6				— —
7				— —
8				— —
9				— —
10				—

E1a /E3: Livelihood activity codes		
Cash or in-kind income from…	7 = Petty trade	14 = Cash, food, or other assistance
1 = Remittances	8 = Pension/social grants 2	15 = Gathering natural products for sale
= Trading staple commodities or	9 = Formal salary/wages	e.g. medicinal herbs, mushrooms, etc.
cash crops	10 = Fishing	16 = Collecting scrap / waste material for re-sale
19= Production & sale of staple crops	11 = Vegetable /fruit production/sales	-8 = Not applicable (No other source) 18 = Other
3 = Trading in livestock Production & sale of cash	12 = Small scale mining/ 20= /quarrying/brick-making	

E3. Which of your household's livelihood activities was most responsible for the change **(reported in E2)**?	|||	Use codes from **E1a/ E3**

Module F: ACCESS TO CREDIT

F1.	Has any member of your household borrowed any cash or goods during the past 2 years? **(If "Yes", go to question F2)** **(If "No", go to question H1)**	|__|	1 = Yes 0 = No

F2.		Has any member of your household borrowed any cash or goods for____in the past 2 years? **(If multiple loans of the same type/ category, enter information for most recent)** **(If "No", go to next row)**	What amount did you ask for? **(If loan was in-kind (i.e., goods or services instead of cash), enter the monetary value of the goods or services requested)**	What amount did you receive? **(If the loan was in-kind (i.e., goods or services instead of cash), enter the monetary value of goods or services received)**	Which household member signed for the loan?	What was the source of the loan?	In what form (did you/will you) repay the loan?
		1 = Yes 0 = No			1=Female 0 = Male 2 = Joint loan		
		a	b	c	d	e	f
1	To purchase agricultural inputs (seed/fertilizer/ chemicals)	|__|			|__|	|_|	|__|
2	To invest in agriculture (e.g., buy tools, equipment, livestock, buy or rent land, etc.)	|__|			|__|	|_|	|__|

3	To start or invest in a non- agricultural business	|__|			|__|	|_|	|__|
4	To pay school fees/sup plies	|__|			|__|	|_|	|__|
5	To purchase staple food for household consumption	|__|			|__|	|_|	|__|
6	To pay for health care / medic al expenses	|__|			|__|	|_|	|__|
7	To pay for social event (funerals, wed dings)	|__|			|__|	|_|	|__|
8	To build or add on to a house	|__|			|__|	|_|	||
9	Other	|__|			|__|	|_|	||

F2e: Codes for sources of credit			**F2f: How credit was/will be repaid**
1= Friend/relative	8 =	Government/Rural Credit fund	1 = In cash
2 = Money lender	9 =	International development organization	2 = In kind
3 = Commercial bank	10 =	NGO	3 = Both c ash and in kind
4 = Informal savings group	11 =	Micro-credit institutions	
5 = Farmers' organization	12 =	Other	
6 = Local trader/ shopkeeper			
7 = Buyer/ trader (contract farming)			

Module G. HOUSEHOLD ASSETS

H1. How many of each of the following assets that are in working order does a member of your household own? **(If an asset is not owned or belongs to a non-household member, write 0)**

		a			a
1	Chair (excluding traditional stools and benches)		15	Hand Mill	
2	Table		16	Bicycle	
3	Bed		17	Harrow	
4	TV/ satellite dish/DVD		18	Plough	
5	Radio		19	Sewing machine	
6	Fishing nets		20	Hammer mill	
7	Canoes		21	Mobile phones/ landline	
8	Axe		22	Maize thresher	
9	Machete		23	silos	
10	Backpack sprayer		24	Tricycle motor/motorking	
11	Hoe		25	Vehicle (car/pick up/motor cycle)	
12	Ox Cart		26	Stove (electric or gas)	
13	Tractor		27	Fridge	
14	Generator		28	Water pump/ treadle pump	

Module H. HOUSING AND AMENITIES

H1. Please indicate the major material of the roof, floor and walls of the main house? **(based on observation – Don't ask)**			**Roof** 1 = Thatch 2 = Iron sheets 3 = Tiles 4 = Plastic	**Floor** 1 = Dirt/ mud/sand 2 = Wood 3 = Concrete 4 = Asbestos	**Walls** 1 = Concrete/fired brick 2 = Mud or mud brick 3 = Mud/wattle
1	Roof				
2	Floor				
3	Walls				

H2. What is the main source of drinking water for your family? **(If "Piped into dwelling", go to question H5)**		1 = Piped into dwelling, yard or plot 2 = Public tap/neighboring house 3 = Well/spring	4 = Pond, lake, river, or stream 5 = Tanker 6 = Borehole 7 = Rain water 8 = Other

H3. On a typical day, what is the total number of trips all members of your household make to fetch water for household use?

H4. Including waiting time, about how much time does one trip to fetch water for household consumption usually take?	a		b	
	(Enter "-7" for "Don't know")	**Record units for time**		1 = Minutes 2 = Hours

H5. What type of toilet facility does your household use?		1 = Flush/ pour flush 2 = Ventilated Improved Pit latrine (VIP)	3 = Pit latrine (unimproved) 4 = None (bush or field)

H6. What type of cooking fuel does your household use		1 = Charcoal 2 = Firewood 3 = Kerosene/paraffin	4 = Gas cylinder 5 = Electricity 6 = Other

H7. What type of lighting fuel does your household use?		1 = Kerosene/paraffin, oil, or gas lantern 2 = Generator/ car battery 3 = Candles, firewood	4 = Solar panel 5 = Electrical network 6 =Torch 7 = Other

Module I: HOUSEHOLD GENDER RELATIONS

I1	In your household who is considered to be in charge of decision making?	Everyone contributes equally	1
		Male Head/Father	2
		Female Head/Mother	3
		Male relative	4
		Female relative	5
		Both female and male	6
		Other (Specify)	7
		Don't Know	8
		Refused	9
I2	In your household who makes decisions about making large household purchases? (Example: Vehicle, furniture etc.)	Everyone contributes equally	1
		Male and Female Heads decide together	2
		Mostly the Males	3
		Mostly the Females	4
		Other (Specify)	7
		Don't Know	8
		Refused	9
I3	In your household who makes decisions about making household purchases for daily needs?	Everyone contributes equally	1
		Male and Female Heads decide together	2
		Mostly the Males	3
		Mostly the Females	4
		Other (Specify)	7
		Don't Know	8
		Refused	9
I4	In your household who makes decisions about visits to distant families and relatives?	Everyone contributes equally	1
		Male and Female Heads decide together	2
		Mostly the Males	3
		Mostly the Females	4
		Other (Specify)	7
		Don't Know	8
		Refused	9
I5	In your household who makes decisions about what food to eat each day?	Everyone contributes equally	1
		Male and Female Heads decide together	2
		Mostly the Males	3
		Mostly the Females	4
		Other (Specify)	7
		Don't Know	8
		Refused	9
I6	In your household, who contributes most of the income?	Children	1
		Male Head/Father	2
		Female Head/Mother	3
		Male relative	4
		Female relative	5
		Other (Specify)	7
		Don't Know	8
		Refused	9
I7	In your household who contributes **THE SECOND MOST** of the income?	Children	1
		Male Head/Father	2
		Female Head/Mother	3
		Male relative	4
		Female relative	5
		Other (Specify)	7

		Don't Know	8
		Refused	9
I8	In your household who usually makes decisions on paying for any health-related expenses?	Everyone contributes equally	1
		Male and Female Heads decide together	2
		Mostly the Males	3
		Mostly the Females	4
		Other (Specify)	7
		Don't Know	8
		Refused	9
I9	Who usually decides what and where to plant?	Everyone contributes equally	1
		Male and Female Heads decide together	2
		Mostly the Males	3
		Mostly the Females	4
		Other (Specify)	7
		Don't Know	8
		Refused	9
I10	Who usually decides what farm products to sell?	Everyone contributes equally	1
		Male and Female Heads decide together	2
		Mostly the Males	3
		Mostly the Females	4
		Other (Specify)	7
		Don't Know	8
		Refused	9
I11	Who usually decides whether you can participate with different local organizations?	Everyone contributes equally	1
		Male and Female Heads decide together	2
		Mostly the Males	3
		Mostly the Females	4
		Other (Specify)	7
		Don't Know	8
		Refused	9

I12 Can your wife (*or you if it is woman*) ever decide to plant crops on own?	Yes	No
I13 Can your wife (*or you if it is the woman*) ever decide to sell crops on her own?	Yes	No
I14 Can your wife (*or you if it is the woman*) ever decide on her own to join an organization such as a village bank?	Yes	No
I15 Can your wife (*or you, if it is the woman*) ever decide to visit family or friends outside the village on her own?	Yes	No
I16a. Do you (*or your husband*) ever help with child care?	Yes	No
16b.1 If yes, how often per month? (circle response) (write any details provided):	Daily	
	Frequently	
	Rare Occasions	
	Never	
I17 Would you (*or your husband*) be comfortable with your wife being in a leadership position in an organization that led her to travel away from home?	Yes	No
I18a. Do you (*or your husband*) ever help with food preparation?	Yes	No
I18b.1 If yes, how often per month? (circle response)	Daily	
	Frequently	
	Rare Occasions	
	Never	
I19a. Do you (*or your husband*) ever do the laundry?	Yes	No
I19b. If yes, how often? (circle response) (write any details provided):	Daily	
	Frequently	

	Rare Occasions	
	Never	
I20. Does anyone in the household drink alcohol?	Yes	No
I21 If someone drinks Can you estimate how often per week this person usually drinks?	Daily	
	Frequently	
	Rare Occasions	
	Never	

Module J: ADAPTIVE CAPACITY AND RESILIENCE

Now I would like to ask you about what you do to manage or cope during drought, flood events and storm surges.			
J1	Which of these events have you experienced in the past 12 months?	Drought	0
		Flood	1
		Storm Surge	2
		Erratic rainfall	3
		None	4
		Other	5
J2	Do you have any coping strategies?	No	0
		Yes	1
		Don't	8
		Refused	9
J3	What specific things did you do to manage the most recent drought/flood/ storm/ other climate event you experienced?	Nothing	0
		Relocate	1
		Sand filling	2
		Drain water	3
		Rely on family or friends	4
		Rely on social network	5
		Rely on government	6
		Rely on humanitarian aid	7
		Sell crops or livestock	8
		Sell assets	9
		Don't know	97
		Refused	98
		No	99
J4	In the past 12 months have you received early warning information about drought, flood/storm events?	No	0
		Yes	1
		Don't know	8
		Refused	9
J5	From whom would you get this early warning information? (Circle as mentioned)	Friends, neighbors, and family	1
		Community leader/ lead	2

		farmer	
		Social networks	3
		Media	4
		Local government	5
		Central government	6
		Private organization	7
		NGOs	8
		Don't know	98
		Refused	99
J6	What changes (if any) in your household have you made because of drought/flood/storm/ erratic rainfall?	None	0
		Relocation out of flood/storm prone area	1
		Change job	2
		Change school for children	3
		Construct flood/storm barriers	4
		Clearance of drainage channels	5
		Change planting times	6
		Changing cultivation methods	7
		Others (specify)	8
J7	How would you rank drought/flood/storm / erratic rain problems relative to other problems in your area?	Low	2
		At par (same)	3
		High	4
		Top priority	5
		Don't know	8
		Refused	9
		Very poor	1
J8	How would you rate your ability to handle flood/drought/ erratic rain related stress?	Poor	2
		Satisfactory	3
		Good	4
		Very good	5
		Don't know	8
		Refused	9

Appendix D: Curriculum Vitae

Name: Kamaldeen Mohammed

Education and Training

Jan. 2020 till date	M.A. Candidate, Department of Geography and Environment University of Western Ontario, Canada Dissertation: Impacts of climate change on food security and smallholder livelihoods in northern Ghana.
Nov. 2014 to May 2018	B.A. (Honours), Geography and Resources Development with Sociology, University of Ghana. Dissertation: Spatial analysis of open defecation and associated health effects in northern Ghana.

Professional Experience

Teaching Assistant University of Western Ontario Jan. 2020 to date	Facilitates tutorials and lab sessions, moderates online classes, holds office hours, proctor and grades student assessments. Courses TA'ed Include Introduction to Human Geography; Geography of Canada.
Youth Researcher, Restless Development and Mastercard Foundation (Contract) Apr. 2019 to Date	Collaborated with a team of 42 young researchers across Africa to collect and analyse data (qualitative and quantitative) regarding challenges faced by young women working in the STEM sector and how to draw on their lived experience to effectively and sustainably link young women to opportunities in the STEM sector in Africa.
Lead Trainer, Development Research & Solutions (Part time) Mar. 2016 to date Dec. 2019	Facilitated the training of participants in quantitative data analysis using SPSS, Stata and R Studio. Led training in introductory GIS using ArcMap, Google Earth and participatory and crowdsourcing GIS data using OpenStreetMap.
Assistant Geospatial Analyst, Gold Matters Project, Ghana Nov. 2018 to Nov. 2019	Successfully analysed and reported on satellite imagery (Landsat, Sentinel, and Rapid Eye) on gold mining areas in Ghana as part of the broader Sustainability Transformations in Artisanal and Small-scale Gold Mining project in Ghana, Uganda and Brazil.
Research & Teaching Assistant, GIS laboratory, University of Ghana Sep. 2018 to Aug. 2019	Led practical laboratory sessions in courses such as Introduction to GIS; Introduction to Remote Sensing Image Analysis; Introduction to Cartography, and quantitative research methods. Assisted in research data collection, analysis and reporting.

Publications

Published

Mohammed, K.., Batung, E., Kansanga, M. M.., Nyantakyi-Frimpong, H., & Luginaah, I., (2021). Livelihood diversification strategies and resilience to climate change in semi-arid Ghana. *Climatic Change: https://doi.org/10.1007/s10584-021-03034-y.*

Under Review

Mohammed, K.., Batung, E., Kansanga, M. M.., Nyantakyi-Frimpong, H., & Luginaah, I., (under review). Intra-household decision-making arrangements and food security in semi-arid Ghana. *African Geographical Review (RAFG-2020-0119).*

Kansanga, M. M., Batung, E., **Mohammed, K**., & Luginaah I., (under review). Beyond purchasing power: The association between sense of community belongingness and food insecurity among the elderly in Canada. *Journal of Aging & Social Policy*

Batung, E., **Mohammed, K.,** Kansanga, M. M.., Nyantakyi-Frimpong, H., & Luginaah, I., (under review). Credit access and perceived climate change resilience of smallholder farmers in semi-arid northern Ghana. *Environment Development and Sustainability (ENVI-2002449).*

Batung, E., **Mohammed, K.,** Kansanga, M. M.., Nyantakyi-Frimpong, H., & Luginaah, I., (under review). Intra-household decision-making and perceived climate change resilience among smallholder farmers in semi-arid northern Ghana. *Gender, Technology and Development (201683033).*

Kansanga, M. M., Konkor, I., Kpienbaareh, D., **Mohammed, K**., Batung, E., Nyantakyi-Frimpong, N., Kuuire, V., & Luginaah I., (under review). Time matters: correlates of timing to food insecurity among smallholder farmers in semi-arid northern Ghana. *Regional Environmental Change.*

Kansanga, M. M., Konkor, I., Kpienbaareh, D., Batung, E., **Mohammed, K**., Nyantakyi-Frimpong, N., Kuuire, V., & Luginaah I., (under review). Gender and timing to seasonal food insecurity: Evidence from semi-arid northern Ghana. *World Development*

Kansanga, M. M., **Mohammed, K**., Batung, E., & Luginaah I., (under review). Lost harvest: Post harvest food loss and food insecurity among smallholder farmers in semi-arid Ghana, *Renewable Agriculture and Food Systems.*

In Progress

Mohammed, K.., Batung, E., Kansanga, M. M.., Nyantakyi-Frimpong, H., & Luginaah, I., (not submitted) Examining the association between alcohol consumption and food insecurity in semi-arid Ghana.

Mohammed, K.., Salifu M.G., Batung, E.,Amoak D., Kansanga M. M.., & Luginaah, I (not submitted). Understanding climatic correlates of malaria prevalence among children in Ghana

Evans B., **Mohammed K**., Konkor. I., Kansanga M.M., Elliot S. (not submitted). Risk perceptions of food allergies in Canada: What are the determinants.

Conferences and Workshops

Conferences

Apr 2021

American Association of Geographers (AAG)
Presentation title: Livelihood diversification strategies and resilience to climate change in semi-arid Ghana

Feb 2021

Environment and Sustainability Conference (EnviroCon)

Presentation Title: Livelihood diversification strategies and resilience to climate change in semi-arid Ghana

Nov. 2020 — Africa-Western Collaboration Conference (AWC). Western University.
Presentation title: Intra-household decision-making arrangements and food security in semi-arid Ghana.

Oct. 2019 — Young Innovation Leaders (YIL) Conference, Accra-Ghana
Presentation title: Disruptive innovations: Implications for healthcare in Ghana.

Aug. 2017 — 2nd Ghana Youth Conference on Climate Change and Sustainable Development, Accra-Ghana. Presentation title: Harnessing rainwater harvesting and underground water storage as alternative flood risk reduction strategies in Tamale, Northern Ghana.

Workshops

Dec. 2019 — Restless Development and Mastercard Foundation, Dar es Salam-Tanzania. Ethics and Safeguarding in Research Workshop.

Jun — Restless Development and Mastercard Foundation, Lusaka-Zambia. Qualitative and Quantitative Research Methods Workshop.

Honours and Awards

Dec. 2020 — Best panel presentation at the Africa-Western Collaboration Conference — $250.

Jan. 2020 — Western Graduate Scholarship, Western University — $32,000 (minimum) per year for two years.

Mar. 2017 — Best project idea at the 2nd Ghana Youth Conference on Climate Change and Sustainable Development, Accra-Ghana.

Voluntary Services

Jan. 2020-till date — Member of international graduate students committee, Western University.

Jan. 2020 till date — Volunteer instructor, GALM Weekend Homework Club for London Middlesex area. (Virtual)
Tutors grade 6 students in maths within London Middlesex Area.

Jul. 2019 – Dec. 2019 — Technical and Talent Manager: Young Innovative Leaders (YIL) Ghana.
Boosted access to the technical resources required for young innovators to conduct market research and design prototype innovations.

Sep. 2015 till date — Member and trainer, Youth Mappers-University of Ghana Chapter.
Crowdsourcing opensource GIS data through community participatory mapping. Training youth on creating opensource GIS data through OpenStreetMap.

Aug. 2017 – May 2019 — Volunteer, Make a Difference (MaD), Tamale-Ghana
Participated in outreach activities where mainly old learning materials are collected and sent to schools in deprived and remote communities in Ghana. Also made learning games for

school children using cardboards

Jul. 2015 – Nov. 2015

Volunteer, Urban Agricultural Network (NGO) Tamale-Ghana
Assisted in the sensitization and experimentation with smallholder farmers on integrating traditional farming practices with mechanized farming practices for sustainable agriculture.

Software Skills

ArcGIS Pro, ArcMap, QGIS, ENVI, Google Earth, R Studio, Stata, SPSS, Microsoft Office